H. S. FRENKEL

TABETIC ATAXIA

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THE TREATMENT

OF

TABETIC ATAXIA

BY MEANS OF SYSTEMATIC EXERCISE

An Exposition of the Principles and Practice of Compensatory Movement Treatment

BY

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ONLY AUTHORIZED ENGLISH EDITION,
TRANSLATED AND EDITED

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WITH 132 ILLUSTRATIONS

PHILADELPHIA

P. BLAKISTON'S SON & CO.

1012 WALNUT STREET

1902

Printed in England.

BOSTON MEDICAL
FEB 24 1903
LIBRARY.

PREFACE

Dr. Frenkel's method of treating locomotor ataxia by systematic and graduated exercise does not claim to influence the tabetic process itself, but to have a beneficial effect on the most prominent symptom of dorsal tabes—the ataxia. The first favourable results achieved by this method were published by the author in a paper read before the neurological section of the Congress of Scientists and Naturalists at Bremen in the year 1889. Since then he has improved and simplified the method, as well as the theoretical considerations on which it is based. A glance at the bibliography at the end of this volume will shew the various stages through which Dr. Frenkel's method passed until it ultimately was put in book form before the profession.

Frenkel's method of treating tabetic ataxia differs from that associated with the names of Professor v. Leyden and Professor Goldscheider on two important points: First, it lays the greatest stress on the careful repetition of movements—in one word, on *practice*, and not on athletic strengthening of the muscles, as v. Leyden and Goldscheider advocate; and, secondly, it requires very little apparatus.

Many, if not most, of the exercises of Frenkel's method are so simple, and need so few mechanical appliances, that every practitioner will be enabled to treat slight and moderately severe cases of tabes at his or the patient's house. It is unnecessary to emphasize the importance of this opportunity of home treatment in cases where pecuniary or other considerations make a stay at a sanatorium a thing of impossibility. Of course, treatment at a sanatorium for several months is the ideal, and home treatment at the very best but a compromise. Yet how many patients are there not for whom the chances of this compromise will mean a new lease of life?

The large number of illustrations will enable the reader to form a clear idea of how the various movements are to be carried out, what apparatus, if any, may be required, in what manner the movements of the patient are to be supervised and safeguarded against accidents.

The present edition is not a translation of Dr. Frenkel's book, but an adaptation of it to the requirements of the medical practitioner, whose chief interest of necessity centres in being enabled to treat the ataxia of his tabetic patient; hence all matter of a controversial or a too theoretical character has been omitted Wherever possible, the English version follows closely the language of the German original; idiomatic difficulties, however, have not infrequently made it necessary to translate rather freely, but every care was taken to preserve the meaning of the original.

Ludwig Freyberger.

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CONTENTS

I. GENERAL PART

	PAGE
The Various Types of Tabetic Ataxia	1
On Coordination	3
Definition of Ataxia	11
The Causation of Tabetic Ataxia	17
The Examination of Sensibility	20
Cutaneous Sensibility	20
The Sensation of Passive Movements in the Joints	22
The Sensation of Voluntary Contractions of Muscles	27
The Examination for Ataxia	28
Examination in Erect Posture	29
Examination during Locomotion	29
Muscular Hypotonia in Tabes	35
The Influence of Hypotonia on the Attitude of the Body	54
The Importance of Hypotonia from the Point of Differential Diagnosis	57
The Relation between Loss of Sensibility and Ataxia	59
Theory of Tabetic Ataxia	62

II. SPECIAL PART

The Practice of Movements	67
Exercise as a Means of compensating Loss of Coordination	69
The Mechanism of the Movements of the Human Body	71
The Foot	72
The Knee-joint	73
The Hip-joint	74
Standing on One Leg	75
Bending the Knees	77
Walking	78
The Mechanism of Walking in Tabetic Subjects	82
Walking Sideways	87
Getting up and Sitting down	90
Mounting and Descending Stairs	91

PAGE

Conditions influencing the Treatment - - - - 94
Spinal Irritation - - - - - - 94
Blindness - - - - - - - 94
Hypotonia - - - - - - - 94
Heart Disease - - - - - - 94
The Control and Protection of the Patients during the Treatment - 95
Dress - - - - - - - - 99
Practice-Rooms and Apparatus - - - - - 99
Size of Practice-Room - - - - - - 101
Diagrams and Other Marks on the Floor - - - - 101
Classification of Exercises - - - - - 105
The Lower Extremities - - - - - 105
A. Exercises for the Recumbent Position - - - 105
The Exercises - - - - - 106
Tempo - - - - - - - 107
Repetition - - - - - - 107
Position of the Practising Leg - - - - 107
Magnitude of Excursions - - - - - 107
Further Exercises - - - - - 108
Exercises for Extreme Ataxia (the So-called Paralytic Stage of Tabes Dorsalis) - - - - - - 119
Exercises in Bed with the Use of Special Apparatus - - 122
Exercises for the Recumbent Position, to be practised with Closed Eyes - - - - - - - 127
B. Exercises in Sitting Posture - - - - 130
Sitting down - - - - - - 132
Getting up - - - - - - 132
C. Exercises in Erect Posture - - - - - 133
Walking Forward - - - - - - 133
Walking Sideways - - - - - 136
Walking Backward - - - - - 137
The Control of the Movements by the Eyes - - - - 138
The Tempo of the Movements - - - - - 139
The Change of Direction - - - - - - 141
Walking Zigzag - - - - - - - 141
Standing and Walking with Bent Knees - - - - 142
Walking on the Narrow Border - - - - - 143
The Practice of Walking in Cases of Severe and Severest (Paralytic) Ataxia - - - - - - - 145
Apparatus for the Practice of Walking - - - - 149
Practising in Groups - - - - - - 154
Ataxia of the Upper Limbs - - - - - 160
The Examination for Ataxia of the Upper Limbs - - - 161
The Shoulder-joint - - - - - 161
The Elbow-joint - - - - - - 161
The Wrist-joint - - - - - - 161
The Fingers - - - - - - - 162

PAGE

The Treatment of the Upper Limbs - 162
Apparatus for the Upper Limbs - 163
The Triangular Block - 163
The Perforated Board - 164
The Peg Board - 165
The Board with Loose Pegs - 165
Coloured Balls suspended from a Bar - 167
Round Discs - 167
Diagrams for Copying - 168
Ataxia of the Body - 172
Duration of the Practice of Movements - 174
The Treatment of Hypotonia - 175
The Results of the Movement Treatment - 178
The Movement Treatment in the Preataxic Stages - 181
The Treatment of the Muscles of the Eyeball - 181
Paresis of the Muscles of the Larynx - 182
Paresis of the Bladder - 182
Bibliography - 183

LIST OF ILLUSTRATIONS

FIG.		PAGE
1.	Normal, Bending the Knees	33
2.	Tabes, Bending the Knees	34
3.	Healthy Subject: Maximum Flexion of Thigh and Knee	37
4.	Healthy Subject: Maximum Flexion of the Thigh with the Knee extended	37
5.	Diagram representing Positions of the Lower Limb with the Knee extended	38
6, 7.	Moderate Hypotonia of Flexor Muscle of the Leg	38, 39
8, 9.	Extreme Hypotonia of Flexors of Leg	39, 40
10.	Moderate Hypotonia of Flexors of Leg	40
11.	Marked Degree of Hypotonia of Flexors of Leg	41
12.	Moderate Hypotonia of Quadriceps	41
13.	Examination for Hypotonia of Adductors (Normal)	42
14.	Marked Hypotonia of Adductors of the Thigh	42
15.	Large Degree of Hypotonia of Flexors of Leg	43
16.	Hypotonia of Flexors of Leg	44
16a.	Examination for Hypotonia of Flexors of Leg (Normal)	44
17.	Abnormal Mobility in Ankle-joint	45
18.	Hypotonia of the Muscles of the Pelvis and Spinal Column	46
19.	Hypotonia of Hand and Fingers	47
20.	Hypotonia of the Flexors of the Hand and Fingers	48
21.	Hypotonic Pseudo-Paresis; Muscular Strength Normal	52
22a, 22b.	Alteration of Posture in Consequence of Hypotonia of the Knee-joint —Normal Posture	53
23.	Marked Hypotonia of the Knee-joints; more obvious on the Right Side	55
24.	The Same, seen from the Right Side	55
25, 26.	Moderate Degree of Hypotonia of the Knee-joints	55
27.	Slight Degree of Hypotonia of the Trunk	56
28.	Moderate Degree of Hypotonia of the Hip-joints	56
29.	Advanced State of Hypotonia of the Hip-joints	57
30.	Hypotonic Outward Rotation of the Left Lower Limb	58
31.	Hypotonic Inward Rotation of the Thigh	58
32.	Normal. Body bent Forward: Thighs and Legs behind the Line of Gravity	73
33.	Normal. Relation of the Perpendicular to the Body in Erect Posture	74
34.	Normal. Maximum Flexion of Hip-joint with the Knee extended	75
35.	Normal. Standing on one Leg	76
36	Beginning Tabes Dorsalis. Standing on one Leg	76
37.	Normal. Leg bent upon the Thigh, which is not moved; Compensatory Bending Forward of the Body	77

FIG. PAGE
38. Normal. Thigh slightly raised, Knee bent. Body moves back into the Perpendicular - - - - - - 77
39. Normal. Bending the Knees while holding the Body erect - - 78
40. Maximum Flexion of the Leg in the Ankle-joint - - - 78
41. Normal. Making a Short Step - - - - - 79
42. Normal. Making a Long Step - - - - - 80
43. Normal. A Step of Medium Length - - - - 80
44. Short Step in Tabes Dorsalis - - - - - 82
45. Long Step in Tabes Dorsalis - - - - - 82
46. Walking Sideways. Initial Position - - - - 83
47. Walking Sideways to the Right. First Phase: Body rests on Left Leg - 84
48. Walking Sideways to the Right. Second Phase: Body leaning towards the Right; Right Foot brought down - - - - - 84
49. Walking Sideways to the Right. Third Phase: Weight of Body resting equally on both Legs - - - - - - 85
50. Walking Sideways to the Right. Fourth Phase: Body resting on Right Leg; Left Heel lifted off the Ground - - - - 85
51. Walking Sideways. Fifth Phase: Body moving to the Extreme Right in order to liberate the Left Leg - - - - - 86
52. Walking Sideways. Sixth Phase: Resumption of Initial Position after the Step is completed - - - - - 86
53. Getting up from a Chair. First Phase: Initial Position - - 87
54. Getting up from a Chair. Second Phase: Drawing the Legs back - 87
55. Getting up from a Chair. Third Phase: The Body is being bent forward - 88
56. Getting up from a Chair. Fourth Phase: Extension of Trunk and Thighs 88
57. Getting up from a Chair. Fifth Phase: Continuation of Movement shewn in Fig. 56 - - - - - - - 89
58. Getting up from a Chair. Sixth Phase: The Movement is completed - 89
59. Normal. Mounting Steps—First Phase - - - - 91
60. Normal. Mounting Steps—Second Phase - - - - 91
61. Tabes Dorsalis. Mounting Steps—Third Phase - - - 92
62. Tabes Dorsalis. Descending Steps—Fourth Phase - - - 92
63. Tabes Dorsalis. Walking Downstairs - - - - 93
64. Supervision of an Exercising Patient - - - - 97
65. Belt for Severe Cases - - - - - - 98
66. Patterns I., II., III., IV. - - - - - 100
67. Zigzag Pattern - - - - - - - 101
68. Footprints - - - - - - - - 102
69. Diagrams for Turning Round - - - - - 103
70. Diagrams for walking Sideways and Backwards - - - 103
71. The Floor Cross - - - - - - - 104
72. Diagram illustrating the Change of Magnitude of the Angle between Thigh and Leg - - - - - - - - 106
73. Illustrating Exercise No. 19 - - - - - 109
74. Illustrating Exercise No. 24 - - - - - 109
75. Illustrating Exercise No. 30 - - - - - 110
76. Illustrating Exercise No. 68 - - - - - 113
77. Illustrating Exercise No. 70 - - - - - 114
78, 79. Illustrating Exercise No. 79 - - - - - 115

FIG. PAGE
80. Illustrating Exercise No. 80 - - - - - 117
81. Illustrating Exercise No. 82 - - - - - 117
82. Illustrating Exercise No. 83 - - - - - 118
83. Illustrating Exercise No. 81 - - - - - 118
84. Illustrating Exercise No. 89 - - - - - 121
85. Illustrating Exercise No. 90 - - - - - 121
86, 87, 88. Illustrating Exercise No. 91 - - - 122, 123
89. Illustrating Exercise No. 92 - - - - - 124
90. Illustrating Exercise No. 93 - - - - - 125
91. Illustrating Exercise No. 94 - - - - - 126
92, 93. Illustrating walking Sideways - - - - 136
94. Illustrating walking with Bent Knees - - - - 143
95. Illustrating walking on the Narrow Border - - - 144
96, 97. Illustrating the Use of the Belt - - - 145, 146
98-100. Illustrating walking on the Floor-Cross - - 148, 149, 150
101, 102. Illustrating walking on the Footprints - - 151, 152
103. Illustrating Carrying Exercises - - - - - 153
104-106. Illustrating walking Sideways in Groups - - 154, 155
107, 108. Illustrating walking Forward in Groups - - - 156
109, 110. Illustrating walking with Arms raised - - 157, 158
111, 112. Further Walking Exercises - - - - 159, 160
113, 114. Illustrating Practice with the Triangular Block - - 163, 164
115-117. Illustrating Practice with the Perforated Board 165, 166
118, 119. Illustrating Practice on the Peg Board - - 167, 168
120-122. Illustrating Practice with Coloured Balls - - 169, 170
123. Illustrating Practice with Coloured Discs - - - - 171
124-128. Representing Diagrams for Drawing Exercises - - 171-173
129. Samples of Handwriting before and after Treatment - - 173
130, 131. Representing a Case of Congenital Hypotonia before and after Application of Orthopædic Apparatus - - - 176, 177
132. Shews the Effect of the Author's Orthopædic Stockings on an Adult Tabetic - - - - - - - 177

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I. GENERAL PART.

THE VARIOUS TYPES OF TABETIC ATAXIA.

In tabes dorsalis several types of motor disturbance may be distinguished, of which each has its own peculiarities and characteristics, although belonging to the general group of disorders of coordination. The curious fact that up till recently very little attention was paid to the peculiarities which distinguish the manifold types of locomotor ataxia is well explained by the existence of an almost universal belief that all symptoms of tabetic ataxia are sufficiently explained by the supposition of pathological changes in the central nervous apparatus. The history of medicine shews many similar instances of a temporary standstill following the discovery of an anatomical cause for physiological and psychological facts.

The symptom which chiefly distinguishes tabetic incoordination from all other anomalies of voluntary movements is the integrity of the entire complex of motor neurones, inasmuch as the cortical ganglion cell, its communication with the ganglion cell of the anterior horn, the ganglion cell of the anterior horn itself, its connection with the muscle, and the muscle itself, exhibit no morbid changes. Physiologically this integrity of the entire complex of motor neurones finds its expression in the preservation of the normal maximum of contraction, or, in other words, the preservation of the muscular power.

As regards locomotion, the following groups may be distinguished:

I. The patient is able to walk about freely, without support, with or without the help of a stick, but his mode of walking is altered.

II. The patient has to lean upon the arm of a companion, with or without the support of a stick; walking alone is impossible.

III. Walking is no longer possible, but the patient can still stand.

IV. Walking and standing are impossible.

Moreover, at the beginning and at the end of this series should be mentioned on the one hand the so-called pre-ataxic stage, and on the other the paralytic stage.

Although the groups which have just been enumerated are classed according to the gravity of the symptoms, it would nevertheless be a mistake to assume that the severity of the disease is commensurate with the amount of loss of compensation in the lower extremities; in other words, the impairment of free locomotion in tabes is not necessarily proportionate to the gravity of the disturbance of coordination. The causes which produce the various degrees of disturbed locomotion may be quite different, and must be well studied, because not only the prognosis, but also the plan and technique of treatment, is dependent on thorough knowledge of them. The inability to walk may be caused by (*a*) the degree of incoordination, which may vary in both legs; (*b*) an alteration of the stability of the body, produced by abnormal mobility in the joints; (*c*) an inability to control the movements of the muscles of the trunk; (*d*) loss of sensibility in the fingers, which makes it impossible for the patient to hold a stick, and so on. In short, we are confronted, not by morbid changes in the centres of coordination, but by a number of problems that can only be solved by a knowledge of the means which enable us to balance ourselves during our movements. It is a fallacy as common as it is fatal to think that pathological forms of locomotion can be understood without a knowledge of the laws that govern normal locomotion.

The power of locomotion is a complex function. If the examination of a locomotor disturbance is to enlarge our knowledge of the anomalies of coordination, it should be made while the patient is lying in bed; the various groups of the muscles of the lower limbs may then be examined uninfluenced by the weight of the body, which otherwise will materially modify the result of the examination. In this position, as a rule, the degree of the incoordination is directly proportionate to the gravity of the disease, but this is not always so. Of several patients shewing the same degree of ataxia in the legs while lying in bed, one will be able to walk alone well, another will want support, whereas the third will be utterly unable to move. The function of the lower extremities is therefore not the sole factor in walking.

The numerous types of tabetic locomotor disturbance have several symptoms in common, which must be included in the definition of the term "ataxia." The first is the integrity of the muscular power; the second is the close attention with which the patients follow with their eyes every single movement they make, whether in bed or out of bed; the third and most important symptom is furnished by the fact that *every ataxic movement becomes more pronounced if made with the eyes closed. There are no exceptions from this law*, which applies to the

erect as well as to the recumbent posture, and can be used for the detection of ataxic symptoms in the majority of the patients who are still considered to be in the pre-ataxic stage. These symptoms, although constant companions of the ataxia, do not explain the nature of the ataxic movements, which are called brisk, throwing, exaggerated, etc. However, so much is already clear that no theory of ataxia can be accepted as satisfactory which does not explain those characteristic symptoms which we have just mentioned. The study of the mechanism of coordination will furnish us with an insight into the nature of those abnormal movements which are the result of "disturbed" coordination.

ON COORDINATION.

The muscles which produce the movements of the body as a whole and of every one of its parts course over two or more segments of the body in such a manner that by their contraction the segments are either approximated or separated. The fulcra of the muscles are mostly parts of the skeleton which are joined together by means of movable joints. Two adjoining and articulated bones form an angle between them, the apex of which is represented by the joint. The magnitude of the angle depends on the degree of contraction of the muscle or muscles which move the joint. The approximation or separation of two parts of the body, therefore, is the result of the enlargement or diminution of the angle that lies between them.

The distribution of the muscles is such that they are not always extended between two apposite segments of the skeleton, but sometimes one segment is passed over, and the muscle or its tendon is inserted into the next but one segment. Thus, a muscle will by its contraction move not one, but several joints; but the magnitude of the various angles formed by the joints is not determined by the ratio of contraction (shortening) of the muscle, as is the case when a muscle is inserted into two apposite segments of the skeleton.

Anatomy describes and names the individual muscles, while the physiology of movements deals with groups of muscles which are distinguished according to their various functions. The contraction of a single muscle (single in an anatomical sense) probably does never occur. It appears that the will-power influences not one muscle, but a group of muscles, which are combined for a common physiological purpose; at least, it needs special training in order to enable the will-power to influence an individual muscle. It is by practice only that *dissociated innervation* is acquired, and with it pro-

ficiency in the *finer* kinds of manual labour, and in that kind of leg-work which is required in some sports and acrobatic performances.

The muscles which belong to one physiological group differ both as to size and insertion; therefore every individual muscle of the group must, during the execution of an intended movement, enter into a certain, but of course for each muscle different, state of contraction.

The term "coordination" denotes the united action of a group of muscles in order to carry out an intended movement; the different degrees of contraction of the various members of a group of muscles may be styled "coordination of muscular contraction."

The task of the muscles, however, consists, not merely in moving the various parts of the body, but also in fixing them in a certain position, *i.e.*, in balancing the weight of a part of the body by means of muscular contraction. Thus, for most kinds of manual work the shoulder and elbow joints must be fixed in a certain position; in moving the legs, in standing and sitting, the trunk must be steadied; in moving the eyes, the muscles of the head and neck, and so on. Even in movements which seem to be produced by a single group of muscles, we see that a large number of remote muscles must be called into play. Whereas it is possible by applying the electric current to stimulate a single muscle to contraction, the numerous individual, and groups of, muscles are at once combined for common action whenever an *intended* movement is to be made; in other words, *the healthy organism knows only coordinate movements*. In standing upright, for instance, all the muscles of the lower limbs and the trunk are in a state of coordinated contraction.

The factors which produce the coordination of the movements are: the quality of the implicated muscle groups, the magnitude of contraction which may be measured with a dynamometer, and the celerity of the movement in the joint, which latter depends on the swiftness of the contraction of the muscles. *Coordinate movements cannot be made unless the three aforesaid factors work well together*. The slightest irregularity on the part of one of them must needs disturb the whole movement. The question whether the three factors work properly together can only be answered by comparing the particular movement with one made by a healthy adult. Therefore the combined action of these three factors of muscular contraction is correct if it results in a movement which is identical with that of a healthy and otherwise normal man. In comparing two voluntary movements, the standard of comparison can only be the purpose for which the movement had been undertaken, assuming at the same time that the movement which

a healthy organism executes for the achievement of a certain intended act is adequate to this purpose—that is, that it is carried out with a minimum of force and the maximum of swiftness required for the occasion. It is impossible to prove this statement to conviction, because there are no scientific methods of examining whether a certain movement was regular or not; such methods are probably impossible. It is not difficult to recognise appropriate movements, but whether the movements which we observe in healthy individuals are the most appropriate ones that the human organism is capable of producing is of course impossible to say. We shall have to revert to this point later, when we have to discuss disturbed coordination.

We must not forget that, in order to judge whether a certain movement was regular or not, we should not only know the purpose for which this movement has been made, but also the conditions under which the movement takes place. A few examples will make it clear. Suppose a man intends to walk from a point A to a point B. If the road is well lighted, smooth and level, the most appropriate way of doing this is simply to walk with ordinary steps; but if the road is dark or slippery or full of holes, the most appropriate way will then be to walk slowly with short steps, straining the muscles to keep the balance. If a person walks over a board on the level ground, his steps will greatly differ from those made when walking over a board which is laid over a ditch; boots which are too large also modify the gait. If the conditions under which a movement is carried out are not all known to the observer, the movement may to him appear abnormal, incoordinate, disorderly. The determining causes may have their origin in certain abnormal conditions of the body itself; thus, a corn or lumbago modify the manner of walking considerably, without at the same time making it less coordinate.

The intended movements of *all* healthy people are not absolutely identical, but differ considerably; these differences, however, are recognised as falling within the category of natural differences. As such we recognise the different ways of walking, of sitting down and getting up, of dancing, sitting on horseback, of moving in society, and so on—in fact, all that physically distinguishes one person from another.

We shall now analyze the laws which regulate the production of coordinate movements, and we shall find that the study of muscular action shews that the principle of " utility " governs every detail of the muscular action. It is well known that the muscles are arranged in such a manner that each group of muscles is opposed by another,

whose action is wholly antagonistic to that of the former. If the contraction of a particular group of muscles (protagonists) diminishes the angle formed between two segments of the skeleton, the antagonists, as the opponent muscles are called, effect its enlargement; if one group rotates a segment of the skeleton in one direction, the antagonist rotates it in the opposite direction, and so on. The moving force of the extremities is furnished by the contraction of the muscles; it is therefore perfectly obvious that all movements of the body are the result of the contraction of certain groups of muscles and their opponents. The analysis of the relationship between protagonists and antagonists must therefore yield the laws of coordination. Yet another mechanical force is made use of in the production of movements of the body, namely, its own gravitation, and we shall see to what a large extent this force is employed. The usefulness of this manœuvre is evident. It is quite clear that all movements could be produced by the action of protagonists and antagonists alone, but it is more useful to save force and to allow a part of the body which had been moved into a certain position by means of muscular contraction to return to its previous position by following its own gravitation. Muscular force and gravitation govern the actions of the human body. The importance of this principle, both for the understanding of the details of each movement and the theory of coordination, impels us to study this relationship more closely, and to illustrate it by examples. A man standing erect with his arms hanging down is bending his arm at the elbow, the flexion being produced by contraction of the biceps. The arm is then to resume its previous position. In theory this may be done in various ways: first, by contraction of the extensors (triceps) and moderate relaxation of the flexors; secondly, by the forearm following its own weight, the flexors at the time being completely relaxed. In practice it depends entirely on the purpose of the movement whether one or the other force is used separately or both together, somewhat after the following scheme: (1) The arm is quickly to return into the hanging position; this is effected by gravitation alone—the flexors are entirely relaxed (extension without extensors). (2) The arm is slowly to return into the hanging position; this is effected by gravitation and gradual diminution of the contraction of the flexors (slow extension by means of gravitation and relaxation of the flexors). (3) The extension of the arm is to take place quickly and with great force; this is done by the combined action of flexors, extensors and gravitation (the flexors acting as a protection against dislocation, etc.).

If the original position be that with the arm raised above the head, the conditions are simply reversed, and the flexion is produced by gravitation and the extensors, and so on. If the arm be lying on a table, so that gravitation cannot act on it, flexion is of course produced by the flexors, and extension by the extensors. We shall see in walking that there is a phase during which gravitation produces a shifting of the trunk. A study of the movements of the human body reveals a wonderful ability of utilizing physical forces for husbanding strength and regulating intervals. A very instructive example in this respect is the employment of gravitation and centrifugal force as a substitute for lost muscular power, as may to a surprising extent be seen in cases of progressive muscular atrophy. This substitution of mechanical for muscular power is the result of the education and adaptation of the remaining muscles, which develop as muscular power is being lost. A simple and instructive example of this substitution was furnished by a patient who suffered from complete atrophy of the musculus triceps brachii, whereas the flexors were quite intact. When the patient was standing, the extension of the arm was produced by gravitation and relaxation of the flexors; when he was lying in bed, the forearm was first supinated *ad maximum*, then flexed, whereby the hand was lifted off the blanket, and then raised until it was level with the face; the arm was then rotated outward and allowed to fall back on the bed again. The effect was the same as that normally produced by the extensors.

Sherrington shewed in 1893 that in cases of contraction of the ocular muscles in consequence of cortical irritation the antagonists are relaxed. In opposition to other authors, we are not able to attribute any importance to this interesting phenomenon as far as the process of coordination is concerned, but believe that it tends to prove that even the simplest muscular contraction possesses some phylogenetically inherent principles of utility. As far as the voluntary movements of the human body are concerned, it is an established fact that the protagonists and antagonists contract independently of one another, and that their concerted action is regulated not by an innate congenital law, but by the necessity and the purpose of each individual movement.

The immense variety of coordinate movements, their complete adaptation to the requirements of the moment, the change in the relations between the moving forces which depends entirely on the conditions prevailing in the objects of the external world, make it impossible to believe that there is a special mechanism situated in the central

nervous system which automatically regulates the coordination of movements. The theory which explains the phenomena of movements by laying the greatest stress on the functions of organs of coordination in the central nervous system could only find acceptance because the enormous change that takes place in the details of every coordinate movement in its course was absolutely ignored. It would never have been possible to try to explain the symptoms of ataxia by presuming the presence of disturbances in centres or tracks of coordination if each incoordinate movement had been analyzed in detail.

Every coordinate movement differs not only as to its purpose, but also as to the external conditions under which it takes place, such as the shape and size of the objects with which the extremities come into touch, their resistance, weight, the conditions of the ground—*e.g.*, as regards its slippery character—and so on. The conclusion is therefore forced upon one that the coordination of muscular contractions for an intended movement must needs depend on centripetal sensations which proceed from the objects themselves—*i.e.*, on sensibility. The fineness of the adaptation of the muscular force to a specific purpose and the selection of muscles has its equivalent in the acuteness of sensation with which the smallest alteration of any of the qualities of the objects of the external world is perceived. The faculty of perceiving the external world would scarcely have any value as regards the precision of the movements of the body if the conditions of the body itself and its parts—or, to be more precise, the position of every one of its limbs at any given moment, and the slightest alteration of this position—could not be signalled with extraordinary velocity and precision. And as, moreover, in the execution of movements muscular contractions play as important a part as the weight of the limbs, *we cannot find a material difference between the laws which govern the relations of the limbs of the body to the objects of the external world, and those that regulate the relations of the limbs to the whole body and to one another*. It is easy to prove by examination how fine is the perception of the position and of the changes of the position of the various parts of the body. We shall deal with this subject more fully when we discuss the technique of the examination for loss of sensibility. We just mention here in passing that cutaneous sensibility, which plays such a dominant part in the work of the hands as regards the objects of the external world, is of comparatively small importance for the perception of changes in the position of the limbs, and that for this task the force-producing organs—*i.e.*, the muscles themselves—possess the most acute perception, a quality the usefulness of which is obvious.

In proving that sensitive impressions are indispensable for the production of coordinate movements we do not deny the existence, or the importance, of central organs which are connected with the coordination of movements; we simply hold that the supposition of the existence of centres of coordination does not furnish an adequate explanation of the manifold phenomena of movements.

As a consequence of the influence exercised by centripetal stimuli on the coordination of movements all coordinate and, what amounts to the same thing, all *orderly* movements must also be *voluntary* movements; for only an act of volition can explain the choice of the muscle groups and their contraction, which alone out of a multitude of possible innervations is adequate to the intensity and celerity of the sensory impressions. The act of choice necessitates a prior act of volition. One might suggest that certain well-known and well-ordered reflex movements, such as the flight and defensive movements of a decapitated frog whose skin is being irritated, are analogous; but the uniform and invariable character of these defensive movements do not permit of a comparison with human voluntary movements; besides, they are not quite as regular and to the purpose as at the first glance it would appear. Physiology teaches us that there is only *one* satisfactory explanation of the defensive movements of the decapitated frog, and this is, that they are movements which had previously been under the influence of volition and choice (Wundt). All the movements of the higher animals which we are bound to consider to be reflex movements—*i.e.*, of which we are sure that they are not under the influence of volition—cannot be compared with coordinated movements. It should be remembered that one necessary characteristic of reflex movements is that the same amount of stimulation of the sensitive nerves always elicits the same amount of muscular contraction, a relationship materially different from the course of a coordinated movement, which, as a reaction intended for the defence of the body against the sensory stimulus, has at its disposition the most varied combinations of muscle groups, and uses them as the position of the body, convenience, and other considerations require.

An attempt has been made to call some apparently uniform acts of muscular activity, such as in walking, an automatic movement; but this is not so. The walking movement is of a uniform character only for so long as the internal and external circumstances remain the same. The slightest alteration of one of these two factors—*e.g.*, mental excitement or a change of the terrain—necessitates a change in the combination and celerity of the muscular contractions. We

know that movements which have been practised frequently are considered "easy," that is, they can be made without producing a feeling of exertion. To assume that because of this absence of exertion such movements take place without an act of volition would be unjustifiable. The chief characteristic of an automatic movement is the *impossibility* of influencing it by the will; such automatic movements are the contractions of the heart. That people may sleep while walking, or give correct answers in their sleep, does not prove anything. It has already been said that the supposition of special nervous centres, whose innervation produces all coordinate movements, cannot be supported on account of the immense number of these movements. On the other hand, the *influence* of the central nervous system on the course of the movements is established beyond doubt; it depends on the ability of the nerve substance to reproduce quickly and unerringly single movements and combinations of movements which had been repeatedly made before. The pathology of the nervous system also shews that this ability of reproducing movements may become more or less impaired (central ataxia). That there are no nervous centres for coordination, as there are for respiration, is fully proved by the fact that all coordinate movements have first to be acquired. The newly-born infant does not make movements which deserve the appellation "coordinate." Not even the movements made in walking, which are in a sense constant, may be inherited. What we observe in the newly-born, besides the automatic movements of the heart and diaphragm, are, on the one hand, the actions of crying, sucking and swallowing, which form a special category of their own, for the reason that even in the adult they are not directly under the power of volition, and are, therefore, automatic reflexes; and, on the other, certain contractions of the muscles of the limbs, which at the very utmost may be said to betray a predilection for certain combinations of movements which are also frequently used during the later part of life. But not even this interpretation is quite free from objection, for we are not at all sure that the flexion of the leg, which is so frequently combined with the flexion of the thigh, is not entirely due to gravitation. We cannot enter here into the details of this question. We would remind the reader that the newly-born baby can neither fix objects with his eyes nor turn round. Physiological experiments, which we can only just mention, have shewn us that coordination may be disturbed first in consequence of peripheral lesions, especially when the posterior roots of the spinal nerves are destroyed; secondly, in consequence of lesions of the cerebellum,

and especially of certain other portions of the brain which are connected with it. But in each case the ataxia is of a different kind. In the latter class of cases the ataxia consists chiefly of an inability to maintain the equilibrium of the body. As sensibility in this case is intact, there can be no doubt that the smaller brain contains organs which maintain the equilibrium of the body, probably by establishing a connection between the centripetal sensitive and the motor impulses. Human pathology confirms the results obtained by experiment, not so much in cases of hereditary ataxia, where we have constantly found the motor disorder complicated by loss of sensibility, as in cases of hereditary atrophy or aplasia of the smaller brain in children. In these latter cases one invariably finds intactness of sensibility and motor power, coupled with the inability to maintain the erect position, which is partly due to an excessive degree of muscular hypotonia (*q.v.*) and partly to loss of coordination. These symptoms of cerebellar incoordination have long been distinguished from those observed in tabetic subjects; indeed, they differ in almost all essential points. The reeling and staggering which characterizes the "cerebellar" gait and resembles that of a drunken man, is entirely different from the careful manner of walking exhibited by tabetics, who always hold their body perfectly stiff. In the most severe cases the patients cannot remain on their feet at all. They fall down in a most characteristic fashion, not as if their legs would give way under them, but they fall very much like a stick which one has let go. *Shutting the eyes does not in these cases increase the motor disturbance.* A careful analysis of the ataxic movements of tabetic patients shews that their movements are adapted to the requirements of the intended action, and that they vary in accordance with the changes in the external conditions. They may be considered to be a reaction to the loss of tactile sensations. The motor disturbances of "cerebellar" patients remain always the same.

DEFINITION OF ATAXIA.

In defining the meaning of the term "ataxia" we shall confine ourselves to that form of disorder of coordination which is observed in people suffering from locomotor ataxia. Types of ataxia of other than tabetic origin will be disregarded, because they differ from that form of ataxia which interests us here, both as regards causation and symptoms.

The tabetic loss of coordination in its simplest and most uncompli-

cated form becomes apparent in the sitting or recumbent posture, when the movement takes place in one joint only, as, *e.g.*, in bending the knee while the patient is lying on his stomach, and so on. The knee-joint allows chiefly of movements round a horizontal (frontal) axis; the lateral movements are so small that they may be neglected. These movements are the result of the combination of muscular contraction and gravitation, and describe normally part of a circle at a rate which experience has taught us to consider as normal. In these relatively simple hinge-joints ataxia becomes noticeable either by (*a*) abnormally rapid movements; or (*b*) by exaggerated muscular exertion, both of the contracting and the apposite muscles; or (*c*) in an unduly prolonged state of muscular contraction, which continues long after the maximum of excursion has been reached—a phenomenon which is caused, not by muscular spasm, but by persistent voluntary innervation; or, lastly, by (*d*) a kind of "staccato" movements, whereas normal articular movements are continuous movements. It depends on the gravity of the case whether one or more, or all four, anomalies are present. The movements which imply more than one joint—and those are the vast majority of the movements—exhibit the same characteristics in various combinations.

This loss of coordination becomes obvious only when the patient makes *voluntary* movements with his limbs, as, *e.g.*, when he tries to bend his knee, or to touch the knee of one leg with the heel of the other. The patient fails either completely to execute this movement or he carries it out in the above-mentioned abnormal fashion.

Moreover, the loss of coordination may result in the patient being unable to keep the limb in the intended position. Here, too, several degrees of ataxia may be observed: either the lower limb, which has been flexed in the knee-joint, can be kept in this position for a longer or shorter period, or there is complete inability to do so.

We have already seen that the loss of coordination does not only become greater when a movement has to be executed with closed eyes, but it is of great interest to observe that those characteristic symptoms which are generally absent when the movement is controlled by the eye appear at once when the eyes are closed; so that, *e.g.*, a simple "staccato" movement becomes, in addition, rapid and throwing.

Careful examination of the lower limbs very frequently, if not always, reveals marked differences as regards their function. These differences may be more or less pronounced. We shall later on have to discuss the importance of these differences as regards the results obtained by our method of treatment, and the theory of tabetic ataxia.

A sign of great diagnostic importance, which is observed very frequently, is the enormously increased range of the active or passive movements that can be made in some joints. These exaggerated movements become possible in consequence of the absence of the contractions of the antagonists. This symptom will be more fully discussed in the chapter on hypotonia.

The power of walking does not depend on the function of the lower limbs alone. A tabetic patient shews the same abnormalities of movements whether he is standing or reclining. The patient, provided he knows himself to be safe from accidents, does not sit down on a chair, but lets himself fall on it; he does not get up from it, but jumps up; he does not put his feet slowly on the ground, but brings them down with great force. Moreover, in walking the legs do not move the shortest way, but make lateral and zigzag movements. This manner of progression is the result of the contraction of groups of muscles which in a state of health are either not called into play at all or participate in the movements to a far less extent.

The clinical examination of a tabetic patient who shews loss of co-ordination but is still able to do his daily work, though perhaps he may want a little support now and then, produces one fact which is of great importance for the proper knowledge of ataxia: the ataxia varies in the same patient and during the same stage of the disease, both in form and intensity. The patient who walks with a stick, leaning upon the arm of a servant, and throwing his legs forward in the well-known manner, will, without support, be utterly unable to walk, or will make short steps, keeping his legs perfectly stiff; the throwing movement of the lower limbs has entirely disappeared, to return only when the former conditions have been restored. The gait of the patient will further change if in walking he is supported by a servant on either side. A change of the nature of the ground over which the patient walks, such as from a carpet to a polished floor, or from that to gravel path, always produces a complete alteration of the patient's gait. Systematic experiments in this direction have succeeded in producing the various types of ataxia in one and the same patient. Thus, the so-called "cock-stride" is changed into a stiff-legged gait; or the stiff-legged gait, with outward rotation of the thigh, is transformed into the well-known throwing and brisk style of walking. One of the most important means of altering the type of ataxia in one and the same patient is furnished by the control which the eye exercises upon the movements of ataxic people. Keeping the eyes fixed on the legs, or looking in front or upward, or shutting them, alters the mode of loco-

motion entirely. The extreme degree of this alteration of the type of ataxia seems to be represented by that condition which is noticeable when a patient who can walk tolerably well when he has his eyes open cannot walk at all, or even falls down, as soon as he shuts his eyes. The appearance which a patient presents when he enters our consulting-room is not alone caused by the degree of the spinal affection, but also by a number of collateral circumstances: whether he comes alone or is attended by somebody who supports him; the condition of his sight and the amount of light in the room; whether the floor is polished or carpeted; or even whether some person or a piece of furniture is near enough to hold on to in case he should stumble. It follows that one can only form an opinion regarding the existence of various forms and grades of ataxia when the patients are examined under exactly the same conditions.

A few remarks must be made on the "cock-stride" manner of walking, which is considered to be a typical form of tabetic ataxia. It is due to an exaggerated throwing, lifting movement of the thigh and by briskly putting the foot on the ground. Contrary to the general belief, this is a rare form of ataxic gait. Wherever it may be observed, it is only present when the patient walks with support, because then he need not trouble himself about the balance and movements of the trunk, and can concentrate his whole energy on moving his legs. A tabetic patient who has to walk alone or without sufficient support never shews the "cock-stride"; on the contrary, he will make short steps, holding his lower limbs perfectly stiff, *provided that he is at all able to walk.*

Every voluntary movement is an intended movement, which has for its purpose the realization of a certain object. A healthy adult person tries to do this—at any rate, as far as the object is familiar to him—by means of appropriate coordinate movements. The various forces that produce these movements—muscular force, gravitation, centrifugal force, etc.—act together in such a manner that the largest possible amount of force is saved. *Coordinate movements, therefore, are such movements of the body which achieve an intended object in the most appropriate manner.* To be strictly logical, all voluntary movements of healthy persons which achieve an intended object in a most irregular manner, or not at all, should be called incoordinate movements. Such movements may be observed in little children when they attempt to stand or walk, or to eat with a spoon, or try to catch some object with their hands; their movements cannot properly be called ataxic.

As in the instance of little children, the same amount of ataxia may be observed in adults who already possess full power of coordination, whenever they try to execute voluntary movements to which they have not yet grown accustomed, as, *e.g.*, riding on horseback, cycling, writing, playing the piano, and various other occupations of a similar nature. At first their movements are entirely unsuitable for the purpose for which they were intended, as may at any moment be observed by comparison with the movements of persons who have become skilled in the pursuits that have just been mentioned—be it that their movements remain futile, or are made with excessive force, or are not completed within the right time.

An analysis of the irregular, or, what amounts to the same thing, unpractised movements of healthy subjects at the commencement of a motor task which is entirely new to them, shews that these movements exhibit the same symptoms that characterize the ataxic movements in tabes. In both cases incomplete coordination is due to irregularity of muscular action and a tendency to make exaggerated movements, haste, neglect of proper intervals, and spastic fixation of the joints. *The execution of the movements becomes still more faulty when the control of the movements by the eyes is eliminated.* All these qualities appear in the healthy as in the tabetic subject only when a voluntary movement is attempted, never when the movement is involuntary. There is no difference in principle between an awkward movement of a healthy person and an ataxic movement of a tabetic subject. That one kind of movements appears to us normal, another abnormal or pathological, has its reason in the fact that the movements of the ataxic are incoordinate even during the most ordinary actions of everyday life, especially as regards locomotion and the position of the limbs, whereas healthy people make incoordinate movements only when executing difficult movements which are unfamiliar to them. Therefore, a voluntary movement of a patient can only then with certainty be considered abnormal or pathological when it is a movement that is frequently performed, such as walking, sitting down, getting up, dressing and undressing, eating, writing, and so on. Whether a person plays the piano awkwardly because he has no practice, or suffers from tabetic ataxia, or whether, when playing billiards, he holds the cue badly on account of want of practice or through locomotor ataxia, nobody can say from a consideration of these movements as such. Nobody can say *a priori* whether a person who has great difficulty in keeping his balance on the ice does so on account of tabetic incoordination or of want of practice. If a person

whom we may see walking in the street putting his legs on the ground in an unusual manner is ataxic or not can only be decided when we know the condition of the road; for when the road is very slippery a healthy person will walk in very much the same manner as a tabetic subject walks on level ground. The criterion of ataxia attaches to a movement as such no more than that of usefulness or coordination; in order to characterize a movement as ataxic, we must have full knowledge of the purpose for which the movement is undertaken, the external circumstances and somatic conditions under which it takes place, and, thirdly, be enabled through experience to form an opinion whether the movement lies within the range of normal movements. For this reason movements should only be examined by means of well-known and familiar exercises.

The ataxic movement is inappropriate because it attempts to achieve a certain purpose in a manner which differs from the one normally adopted for the same purpose. To make this definition complete, there must be not only identity of purpose, but also identity of the internal conditions. A knowledge of the internal conditions may lead us to consider as appropriate a movement which to a superficial observer will appear as wholly irregular. The alteration of the movements of the lower limbs of an ataxic, which we have considered above, the employment of the "cock-stride" only when the patient is walking with support, the use of short steps on unsafe ground, or when walking without support, prove that the tabetic have not entirely lost the faculty of adapting, however imperfectly, their movements to the requirements of the moment. The study of the causes of ataxia will shew that the internal conditions under which the tabetic patients have to make their movements are such as to make these movements the most appropriate under the circumstances; in other words, the "incoordinate" movements of a tabetic subject must be considered the most appropriate reaction to his abnormal nervous condition, and should not be taken as the result of the abolition in his instance of the general principle of the employment of the smallest possible amount of force.

THE CAUSATION OF TABETIC ATAXIA.

It is surprising to find that among clinical observers no agreement has been arrived at as to the causes that produce ataxia. In this controversy two questions play an important part. First, what is coordination, and where is its centre of localization? and, secondly, is disturbed sensibility a *constant* symptom of ataxia or not?

One group of theories can be classed under the heading of "motor" theories. They seek the seat of the disturbance in the motor portion of the central nervous system, be it either in the spinal cord or the brain. Their argument is as follows:

There is no loss of force or contractibility of the muscles. Dynamometrically the muscles appear to be quite normal. What is lost is the harmonious cooperation of the muscles, or, in other words, the coordination, for the nervous impulses are not properly conducted along the motor paths in the spinal cord. Consequently, the ataxia is caused by morbid changes in the efferent spinal nerves. As, however, the nerves which conduct the simple motor or contraction impulses are obviously intact, this theory necessitates the assumption of the existence in the spinal cord of special paths for the coordination impulses. In order to make this theory harmonize with the anatomical conditions, a subsidiary hypothesis is introduced, namely, that these coordination fibres, in spite of their being efferent fibres, are situated in those parts of the spinal cord which, as a rule, are reserved for afferent fibres only (viz., the posterior columns); and the defenders of this theory refer to the analogous conditions which obtain in the lateral columns, with regard to which it has been proved that they contain both afferent and efferent nerve fibres.

This theory would be acceptable if it would explain the ataxic motor disturbance in such a way that one could base on it an exhaustive description of the affection. This, however, is not possible, for the "spinal" theory, as we will call it, presumes as a matter of course that all motor impulses are intact; according to it, all voluntary innervations take place in a perfectly normal manner; the disturbance is situated in the conducting fibre, and represents a modification of the conducting power of the fibre. It is, indeed, thinkable, if the fibres of a nerve-bundle which innervates a certain group of muscles undergo a modification of their conducting power, both as regards velocity and intensity, but which is different in each individual fibre, that the symptoms of ataxia may appear. At the same time, it would be

necessary to assume that this anomaly of conduction is constant, that it does not vary from moment to moment, and, above all, that retardation of innervation does not follow acceleration in irregular sequence. Now, we know that ataxia as a motor disturbance is not at all constant. We have only to recall the example which we quoted on a previous occasion, that if a patient enters the consulting-room stamping with his feet at every step he takes, it is sufficient to support him in some manner, or to let him lie down, in order to bring about a complete change in his movements, even if they take place in precisely the same groups of muscles. The cardinal point that awaits explanation is, that not only ataxia in general, but every single ataxic movement in one and the same patient, changes from one moment to the other; that is to say, the individual muscular contractions which constitute the movement modify themselves in the most varied fashion whenever the conditions are altered under which the movement is to take place. It cannot be accentuated too much that this alteration of the individual ataxic movement is a phenomenon which has no parallel in the pathology of movements, and which is not sufficiently explained by the supposition of a lesion in some coordination fibres. Moreover, the expression "coordination fibre" is physiologically inexplicable, for if motor impulses are by the centres sent along any motor fibre with normal intensity and velocity, the motor fibre has nothing to do but to conduct them in order to excite appropriate muscular contractions, and thus coordinated movements. Any motor fibre will be perfectly suitable for this purpose. Quite apart from other difficulties, it is impossible to assume that the will uses one set of nerve-tracks for coordinate movements and another for other motor manifestations, for the intensity and duration of every motor effort is determined in every single muscle fibre which *ipso facto* represents one of the elements that compose the coordinate movement. Men like Erb and Charcot have defended the "spinal" theory, not so much because it seemed sufficiently to explain the various symptoms of ataxia, as because there were no positive proofs in favour of the theory which assumes the existence of disturbances of sensibility. The chief objection to the assumption of disturbances of sensibility is that there are cases of tabetic ataxia without loss of sensibility, and others of loss of sensibility without ataxia.

If these objections regarding the loss of sensibility hold good, then indeed cannot tabetic ataxia be explained by reference to disturbances of sensibility. But the "spinal" theory does not find favour with all clinical observers who adhere to the "motor" theory of ataxia.

Certain peculiarities in the behaviour of the patients, conspicuous differences in the manner and extent of the motor disturbances, the change which the ataxia undergoes whenever the external conditions alter, have induced many to think that there must be a central lesion that produces ataxia.

Jendrassik in 1888 formulated the "cerebral" theory of ataxia, namely, that lesions of the centres of coordination and association in the brain are alone able to explain the whole complex of ataxic symptoms. Apart from the anatomical signs with which Jendrassik sought to support his theory, and which were soon proved to be inconstant, this new theory denotes a decided advance, because for the first time the details of the ataxic disturbance have not been simply ignored, and because each patient was examined for the special peculiarities of his, if we may say so, personal ataxia.

More recently Raymond has enlarged Jendrassik's theory, especially as regards the psychological side of it. He considers ataxia a consequence of a psychological change; the various and ever-changing symptoms of tabes are to him, like the ataxia, the result of an altered state of cerebration. Raymond stated his theory in a paper which dealt with the treatment of ataxia by exercises. The favourable results gained by this method are to him a new and cogent proof of the cerebral origin of ataxia.

Thus we see that a motor anomaly present in a certain well-defined disease, and accompanied by a constant anatomical change in the spinal cord, is made to depend on a psychological change of some sort or other, which, however, has neither an anatomical foundation nor does it produce any other mental symptoms whatsoever. The symptoms which induced Raymond to form his conclusions are, first, the peculiar variability and the inconsistence of the symptoms of ataxia itself, and, secondly, the experience that psychological influences, such as will-power and practice, improve these symptoms, and in some cases even make them disappear altogether. It is clear that a theory such as Raymond's makes the problem only more complicated and more difficult to understand, for it introduces a mysterious element into the mechanism of ataxia which entirely evades our grasp.

Yet one lasting gain has resulted from this succession of theories, namely, the knowledge of certain peculiarities in the appearance of the ataxic motor disturbance, such as its modification by, and the adaptation to, the conditions under which each individual movement takes place.

An entirely different path is followed by the "sensory" theory of

ataxia. According to this theory, the motor functions of the centres as well as those of the conducting fibres are normal. The motor anomaly is made to depend entirely on a disturbance of sensibility. As the latter is caused by the lesion of the posterior columns of the spinal cord, which is a constant anatomical change characteristic of locomotor ataxia, this theory declares the anatomical process solely and exclusively responsible for the motor disturbance. If a disease is characterized by a constant anatomical change, it is evident that it is one's duty to subordinate all symptoms to this one lesion as long as no insuperable obstacles arise to such a course. At first the representatives of this theory paid more attention to the loss of cutaneous sensibility than to the loss of sensation in the muscles and joints. The general idea which underlies this theory is that, in order to produce normal movements of the limbs, the sensory impressions proceeding from them must also be normal.

THE EXAMINATION OF SENSIBILITY.

1. Cutaneous Sensibility.

The results of the examination of the sensibility of the skin are of the greatest theoretical interest, quite apart from their importance as regards the question of ataxia. The majority of patients shew a typical condition of cutaneous sensibility, which is able to throw a new light on the onset and development of tabes. Among 200 patients suffering from locomotor ataxia were very few who did not shew some loss of cutaneous sensibility. They were chiefly patients in the initial stage, who had no, or only a slight degree of, ataxia; but severer cases of tabes, especially those who could not walk at all without support, always shewed marked loss of cutaneous sensibility.

We know very well that our statement is opposed even to the opinion of those clinical observers who hold that ataxia is caused by a loss of sensibility, and we believe that the result of the examination of cutaneous sensibility in tabes depends largely on the manner in which the examination is conducted.

The first thing to remember in examining tabetic patients for loss of cutaneous sensibility is that there is hardly ever complete anæsthesia, but that cutaneous sensibility is more or less diminished. Secondly, in the majority of cases one finds impairment of tactile sensibility only, whereas other sensations, such as those of heat and cold or of pain, are either quite intact or deficient in certain areas only.

Lastly, the patients suffer often from paræsthesia, or, in other words, they hallucinate sensations. The absence of total anæsthesia demands that the skin should be touched very lightly; when the sensation of hot and cold is found intact, it is necessary that the instrument with which the examination takes place has the same temperature as the skin of the patient. It is extremely difficult even for highly intelligent patients to distinguish between sensations of touch and temperature, because our tactile sensations are always accompanied by a sensation of hot or cold. To the neglect of these elementary precautions is no doubt due the fact that many incorrect statements are to be found in text-books regarding the question of cutaneous sensibility.

The best method of examining is by using the finger-tips. By rubbing or submersing in hot water the hand with which the examination is to be made, its temperature is raised sufficiently to correspond to the temperature of the skin of the patient to be examined. With the tip of the forefinger the skin is then very gently touched; the sensation which the patient feels gives a good idea of the lightness of the touch. The use of the finger-tips eliminates all the sources of error which are created by employing pointed instruments or pencil-brushes or cotton-wool, whereby either painful or tickling sensations are produced which completely blur the tactile impression. The patient is prevented from hallucinating tactile impressions, as invariably happens when he is asked to state whether he "feels anything," by being told beforehand that his skin will be touched with the tip of the finger, and that he will have to concentrate his whole attention thereon. If these precautions are taken, the results obtained in subsequent examinations never vary. It is not at all rare to find that a patient who is being examined in this manner promptly and correctly "spots" the lightest touch—in other words, shews normal cutaneous sensibility. But when he is asked to compare the tactile impressions received in two separate parts, such as the legs, he invariably states that he feels the touch more distinctly in one leg than in the other. We propose to call this condition *relative hypæsthesia*.

This hypæsthesia is a constant symptom. Repeated examinations shew without doubt that there is a diminution of sensibility on one side; but this does not mean, of course, that the other side possesses normal sensibility. Unquestionably, even the most delicate pressure with the finger cannot give us an exact information regarding the apperceptional value of the equivalent tactile impression received by the patient. One might object that a method of examination employ-

ing almost imperceptibly differing tactile impressions is likely, even in healthy persons, to yield results of a somewhat doubtful nature. But in reality this is not the case. A healthy person perceives the most delicate tactile impressions promptly and in symmetrical places with equal precision. For this reason we felt justified in diagnosing impairment of cutaneous sensibility in a patient who correctly indicated the symmetrical places where he had been touched with the finger, but felt the touch on one side more distinctly than on the other. It appears to us probable that even those cases of slight ataxia who do not shew disturbed cutaneous sensation possess a large number of anomalies of cutaneous sensation which escape our present methods of examination. There is, however, a limited number of patients who doubtless have ataxia, but in whom one cannot find any appreciable alteration of cutaneous sensibility. It is impossible to establish a proportional relationship between the ataxia and the loss of cutaneous sensibility. The only conclusion that can be drawn, therefore, is that impairment, or loss of cutaneous sensibility, has nothing whatever to do with general ataxia, but only with one special form of ataxia, inasmuch as it may serve to explain the swaying to and fro, in consequence of plantar anæsthesia, when the patients are standing with their eyes shut.

2. The Sensation of Passive Movements in the Joints.

Loss of sensibility, as regards passive movements of the limbs, could be observed in every tabetic patient in whom the ataxia was either manifest or could be made visible under certain circumstances. There is no exception to this rule, and we have often been able to demonstrate with certainty the presence of ataxia in patients in whom previous observers had not succeeded in finding any disturbance of sensibility. It is obvious that the examination for these disturbances of sensibility requires special precautions—not in advanced cases, it is true, but in those milder cases of manifest ataxia in whom loss of coordination is not attended by absolute helplessness. Such cases, however, are rare.

The examination for the loss of sensation of passive movements in joints is made by moving the peripheral part of a limb slowly round the axis of the joint, while the central part is kept in a fixed position. In executing these movements, the following precautions must be observed in order to obtain a definite result:

(*a*) The movement must be made very slowly; if it is made too quickly the presence of sensory disturbances might easily be overlooked. It is a common experience to see that rapid excursions are correctly stated, whereas slow, almost imperceptible movements are not felt at all.

A symptom of this kind, which is always present, is found in making passive movements of the toes. In healthy subjects the slightest passive movements in the joints of the great toe are most correctly felt; but we have seen many cases of ataxia in whom, in spite of apparent intactness of sensibility, the presence of a severe sensation disturbance could be proved if the passive movements were executed slowly, and no pressure was exerted which could have indicated to the patient the nature of the movement in progress. Thus we could demonstrate that a patient whose sensibility was apparently perfect did not know what position his great toe occupied, which at the time was being kept in extreme dorsal or plantar flexion.

(*b*) It is therefore absolutely necessary that every, even the slightest, pressure should be avoided which could enable the patient to make a guess at the nature and direction of the movement, even though he does not feel it. In severe cases of tabes it was not difficult, by means of the exertion of pressure on the legs, although they were kept perfectly still, to produce in the patients the idea that their legs were being moved; a healthy subject, on the other hand, always draws a sharp distinction between pressure and movement. When the cutaneous sensibility is less affected than that of the joints, the patient derives his knowledge of the position of his limbs from the various impressions he receives through the sensitive nerves of the skin. A change of the points of support and contact with the hands of the person examining, change of position, and so on, go far towards supplementing or supplanting partial or complete loss of articular sensibility, and may thus obliterate the results of the examination, the more as the patient who is being examined often has not the slightest knowledge of the deception which his statements produce.

The following are the rules which should be observed at the examination: During the movement the hands are to be kept in the same place: they hold the limbs, using the same amount of force throughout; friction on the blankets or sheets is to be avoided. While the knee-joint is being examined, the patient should lie on his stomach, thereby avoiding flexion in the hip-joint. If we take as an example the examination for the sensibility to passive movements in the knee-joint, the

examination should be made in the following way: The patient lies on his stomach; the thigh is held firmly with one hand just above the knee (left hand for left knee), while the other hand grasps the leg just above the ankle and lifts it up slowly. The examination of the hip-joint is more difficult, on account of the contraction of the flexors of the leg which takes place as soon as the extended limb is raised. We are therefore obliged to execute the movements in the hip with the leg flexed in the knee-joint. All sources of error can be eliminated if during the experiment the angle between leg and thigh is kept unaltered, or if the leg is first fixed in extreme flexion upon the thigh, by means of a bandage, before movements in the hip-joint are begun.

(*c*) During the examination of passive movements special attention must be paid to the *voluntary contractions* which always take place in the muscles round the joint that is being examined. These contractions are an important, *if not the most important*, means which the patient has for finding out the exact position of his limbs. If, *e.g.*, we examine for sensibility of the knee-joint in the manner just described (abdominal position, etc.), we observe that the moment the patient is asked to describe the movement or position of his limb, a contraction of the flexors (biceps, semitendinosus, etc.) invariably takes place. By means of this contraction the patient tries to inform himself as to the position of his limb; in a manner of speaking, he "gropes" with his muscles, presumably the tendinous insertions; his measure is the muscular tension which is just sufficient to balance the limb in a certain position. These muscular contractions are evidently voluntary; nevertheless, the patient becomes conscious of them only by concentrating his attention on them. The following experiments were made with healthy persons in order to study the importance of these muscular contractions for the recognition of the positions of the limbs; they were made with a medical man who was kind enough to submit himself to quite a series of experiments.

The experiments were arranged in the following manner: Mr. X. is lying on his back with his eyes closed. Repeated preliminary experiments have enabled him to allow passive movements of his limbs to be made without the slightest reaction on the part of his muscles. One of his lower limbs is passively flexed in the hip and knee joints, and fixed in a certain degree of flexion. He is now asked to bring the other limb into the corresponding position. It becomes at once obvious that he constantly makes the mistake of flexing the free limb more than the other with which the passive movements are carried out. If

one tries to mislead him by aimlessly moving the limb about before fixing it in a certain position, then the mistakes which the other—actively moving—limb makes become much greater. This mistake, however, is at once corrected if Mr. X. is permitted to make slight muscular contractions in the limb that is being kept in a certain position, but without altering the position of the latter. If he is permitted to make these muscular contractions during the passive movement, then he makes no mistake whatever; if they are permitted *after* the fixation of the limb, the mistake made with the free limb is at once corrected, so that both limbs are held in the same position. It follows from these experiments, if in a healthy subject an extremity be actively brought into a certain position, that the other limb is at once brought into the same position. It is perfectly obvious from these experiments that the sensations which are produced by movements of the articulations, tension of the capsules and ligaments, and pressure exerted on the tissues, etc., are quite sufficient to inform one as to the actual movements and their direction, and to give one an *approximate* idea of the extent of these movements. An *exact* idea of the position of the limbs such as is necessary for the purpose of an intended movement is furnished to the mind by the sensations that are produced by contractions of the muscles, be it that the muscles themselves or the tendons are the sensitive structures. The motor apparatus works, like all instruments of precision, with a coarse and fine adjustment; the coarse adjustment is the articular sensation, the fine adjustment the sensation furnished by muscle and tendon.

We have already seen that tabetic subjects contract their muscles during passive movements whenever they are questioned about the position of their limb. *These muscular contractions obliterate a moderate degree of loss of articular sensibility* to such an extent that the latter appears to be normal, although it shews marked irregularity as soon as all compensating factors are recognised and eliminated by the person who conducts the examination. We have already remarked that even healthy subjects are not always exact as to the position of their limbs if they have to abstain from all muscular contractions. But in them the muscular contractions act like a fine adjustment; the direction and approximate amplitude of the movement is with sufficient exactness gauged by means of articular sensations. On the other hand, ataxic persons have lost their articular sensibility to such an extent that in the absence of muscular contractions they are quite unable to give an account of the direction in which their limb moved (whether plantar or dorsal flexion, flexion or extension), even in cases

where movements are perceived apparently well, so long as muscular contractions are permitted.

Loss of articular sensibility is a constant and never-absent symptom in all cases of tabes which shew even a slight degree of ataxia. The following classification might be made: (1) Slight ataxia of the lower extremities (made visible only by special manœuvres or complicated tasks of coordination); the loss of sensibility in the joints of the toes, foot and ankle can be completely compensated by voluntary muscular contractions. (2) Obvious but moderate degree of ataxia (visible during all movements, but especially during locomotion); articular sensibility in the joints of toes and foot much reduced, cannot be completely compensated by muscular contractions; partial loss of sensibility in the knee-joints, which can partly or wholly be compensated by muscular contractions. (3) Extreme degree of ataxia (locomotion impossible or dependent on support); articular sensibility lost in all joints which take part in locomotion (joints of foot, knee, hip); muscular contractions cannot fully compensate the loss of sensibility because the articular disturbance is very great, and the *muscular sensibility itself is reduced.*

This schedule comprises the symptoms which are usually met with in the large majority of cases. The groups of symptoms may of course vary; it sometimes happens that a more proximal joint is affected earlier or more intensely than a more distant one, as, for instance, in tabes cervicalis with ataxia of the upper limbs.

The fact that one constant symptom of tabetic ataxia is loss of articular sensibility, and, further, that within certain limits voluntary contraction of the muscles is able to compensate that loss, allows us to conclude that in ataxic persons voluntary contractions of muscles accompany active and passive movements of the limbs to a much greater extent than is the case in healthy subjects. This theory is borne out by clinical observation.

When examining for loss of sensibility, it is absolutely necessary that the patients should thoroughly relax their muscles. Even healthy subjects have great difficulty in doing this at the first visit. The patient must be gradually taught to leave his muscles quite limp, no matter what movements are executed with his limbs. In ataxic subjects these muscular contractions may become so strong that examination becomes impossible, the limbs resist passive movements, and if during the examination one lets the limb go, it does not fall back on the bed, but remains in its former raised position, and so on.

3. The Sensation of Voluntary Contractions of Muscles.

A well-known and very frequent symptom of locomotor ataxia is the partial or total loss of orientation of the extremities. The patients have only a partial or no knowledge whatever of the position of their limbs, whether they are lying in apposition or are crossed, whether one lies higher than the other, and so on. These symptoms appear when the muscular contractions do not any longer furnish the mind with an idea of the relations of the articulating surfaces to one another. It is the consequence of the loss of sensibility *of the muscles themselves or of the tendons* which invariably appears in the course of the disease, although much later than the loss of perception of passive movements. In this stage of the disease the patient is no longer able when he shuts his eyes to bring one limb into a position similar to that already occupied by the other. The examination is carried out in the following manner: The lower limb (*a*) (or a single joint of the lower limb) is brought into a certain position and then held firmly. The patient, with his eyes shut, tries by means of the remainder of his articular and muscular sensibility to inform himself of the position occupied by his limb, and then attempts to bring the lower limb (*b*) into the same position as (*a*). The mistake which he makes in this attempt gives us the measure of his ataxia. This measure is of course not absolutely correct, on account of the abnormal condition of the lower limb (*a*), for it is very rare for locomotor ataxia to affect only one lower extremity. The test enables us only to draw a conclusion as to which limb is the more hypæsthetic. Physiology teaches us that a strong innervation creates the impression of a powerful muscular contraction even if from pathological reasons the muscle did not contract at all, or only very insufficiently; this has its reason in centripetal impulses which arise in the muscular insertions. When the sensibility of the muscles becomes altered, these centripetal impulses cannot any longer serve as a measure of contraction, and the result is ataxia. If in tabetic subjects, especially in advanced cases, the muscles are stimulated with the Faradic current, the contraction of the muscles is felt only when the coils are brought close together, and in many cases the contraction is not perceived at all; when the contraction is felt, sensation is invariably delayed.

We have described the technique of the examination for loss of sensibility at such length because we are convinced that valuable results can only be achieved by a knowledge of all sources of error and

of the means of avoiding them. *Manifest tabetic ataxia is mostly combined with anomalies of cutaneous sensibility*, and is *always* coupled with loss of articular sensibility; severe ataxia, besides, shews loss of muscular and tendinous sensibility. The contention that there are cases of tabetic ataxia in whom there is no loss of sensibility whatever can only originate from faulty observation.

The various manifestations of sensory disturbance which we have just enumerated, of course, do not represent the cause of ataxia; they even do not prove a connection between these two morbid symptoms, but they remove the strongest objection to the "sensory" theory of loss of sensibility.

THE EXAMINATION FOR ATAXIA.

The ankle, knee, and hip joints must be separately examined for loss of coordination. The ankle-joint, having only a limited mobility, shews the least amount of ataxia. The examination for ataxia in the knee-joint requires some skill, for it is necessary to conduct the examination of this joint so as to prevent flexion of the hip-joint. The patient should lie on his stomach and his thigh be held down on the bed, in order to prevent rotation. This position has one disadvantage: it excludes the control of the movements by the eye. It is therefore advisable in severe cases to let the patient sit on a chair and to fix his thigh with the hand. In lighter cases, on the other hand, the exclusion of ocular control of the movements by the patient himself has this advantage, that it makes visible even slight degrees of ataxia. The movements to be tried are extension and flexion; the test should confine itself to the examination of the tempo and uniformity of these movements, and to a comparison of both sides. As regards the hip-joint, the examination of this joint should comprise flexion, adduction, abduction, extension, and rotation. All these movements should be tried singly and in various combinations. For the practice it is important to remember that adduction and abduction of the thigh with extended leg, whether supported by the hand or resting on the bed, requires much muscular force, and is therefore not suitable for the examination for ataxia in the hip-joint. Adduction and abduction of the thigh with the knee flexed is, however, very instructive. The patient should lie on his back; his leg is flexed upon the thigh and moved inward and outward. This test produces a movement of abduction and adduction which is exceedingly interesting. In slight and moderately severe cases this movement does

not take place in a steady and regular manner, but in a peculiar staccato fashion. The number and intensity of these jerks furnishes a good basis for estimating the severity of the ataxia in the various groups of muscles that take part in the movement. In very severe cases this movement is absolutely impossible of execution; from the initial position the patients let the thigh fall outward as if it were paralyzed.

In trying to classify the various degrees of ataxia, it should be remembered that those patients who from their examination in bed seem to belong to the same class shew quite different types when examined standing or during walking. Not only the weight of the trunk, but the incoordination of the trunk muscles themselves, influence the movements of the body in many ways. The mental condition and the temperament of the patient have as much influence on his coordination in standing or walking as the smoothness or darkness of the road, the proximity of support, and so on. *It is therefore absolutely necessary in discussing the parallelism of loss of sensibility and ataxia to see first that the patients are examined under the same conditions.*

Examination in Erect Posture.

The examination begins with standing in erect posture. The distance between the two feet should be noted first; the broader the base, the easier is it for the patient to balance himself. Secondly, the patient should move his body in various directions without leaving the place where he stands; the patient should also sit down and get up from a chair, and bend his knees, trying at the time to keep his body erect. In these movements control by the eyes on the part of the patient plays a most important part. If the patient looks away from his feet for a moment only while going through these exercises, the manner and degree of the ataxia becomes at once changed.

Examination during Locomotion.

Here the patient is to be examined for his ability of walking with or without support. The kind of support required is to be ascertained. It should be remembered that the support by an attendant, be it ever so slight, is of much more help to the tabetic than a stick. If, therefore, a patient cannot dispense with the support by an attendant, he is more severely affected than one who walks with one or even with two sticks. The examination will also shew how the patient puts his feet on the ground and how quickly he can walk.

Walking quickly, independently, and without support, is one of the most difficult tasks for tabetic patients. Running is one of the first movements that tabetics lose in the progress of their disease. The important part played by the eyes in such movements as walking and running should not be ignored.

If the motor power of the patients be examined systematically and in the manner which we have just described, a number of symptoms will be found which are of importance for the theory and treatment of ataxic movements. By careful examination of the patient in bed, very slight degrees of ataxia can be recognised. For this purpose it may be necessary to let the patient make certain movements with special precision, if required with his eyes shut. A healthy subject, lying on his back, will make all movements with both legs with the same precision whether he keeps his eyes open or not; the tabetic, on the other hand, in his movements depends entirely on the control by his eyes. By means of this test it is possible in the majority of apparently pre-ataxic cases to detect definite loss of coordination. One is also enabled to compare the degree of ataxia in both legs. With the exception of very slight cases of commencing ataxia, where one could have doubts as to the result of the examination, *we have not examined a single patient in whom both legs had been affected to the same degree.* We always found one leg more ataxic than the other. In many cases the patients themselves were not aware of this circumstance. But even in those patients who were conscious of having a "weaker" leg, this sensation of weakness in one leg did not always correspond to the actual condition found at the examination for ataxia. One patient, for instance, when standing on one leg, could balance himself better on the ataxic leg than on the other. It is probable that the more ataxic leg, being more hypotonic than its less affected partner, and in consequence of the formation of genu recurvatum, is less liable to double under the patient than the other.

The larger the angle which is formed by the thigh and leg, the greater is the difficulty which the patient experiences in holding his lower limb in a certain position; it is easiest for him to keep the leg bent *ad maximum*, so that the heel touches the thigh. For the same reason the patient experiences less difficulty in resting the heel of one foot on the opposite knee than in putting it on the opposite leg or ankle. If the patient tries to abduct his lower limb while the knee-joint is bent, so that the sole of the foot rests upon the bed, and then to bring it back into the former position, he cannot do so otherwise

than by a series of jerks, which may be so violent as to throw the limb about from one side to the other. The patient invariably states that he cannot help those jerks, that they happen against his will, and so on. In consequence of such statements, many observers have mistaken those jerks for involuntary movements. They are, of course, mistaken. Another ataxic movement is of the greatest diagnostic value, especially as it may be found quite early in the course of the disease, long before other ataxic disorders become prominent. Supposing the patient lies on his stomach, and is asked to lift up his leg—*i.e.*, bend his knee. The way in which he executes this movement is very interesting. The patient, *e.g.*, cannot bend or stretch his knee slowly. The extension of the joint does not take place slowly, but the leg is let fall on the bed; in flexing it the leg does not move in a vertical plane, but has a tendency of falling inwards—in severer cases even outwards. In the latter case the leg is rotated, in consequence of loss of sensibility in the hip-joint and the muscles of the thigh. These movements are produced by excessive, almost spastic, contractions, so that the patient often continues to contract his muscles long after the movement itself has come to an end. One or the other of these symptoms is nearly always present. In most cases they are just noticeable; in severe and grave cases the movement becomes partially or wholly impossible, or is executed in a perfectly chaotic manner. The diagnosis of this anomaly of movement is of greater importance than the usual test of standing on one leg, etc., because it is quite independent of individual conditions, habits, nervousness, and so on. There are healthy people who cannot balance themselves on one leg with their eyes shut; and, on the other hand, there are tabetics who can do it tolerably well; but we have not yet seen a healthy subject who has shewn the anomaly which has just been described. These symptoms become exaggerated when the same movement is made simultaneously with both legs. Keeping the eyes shut during the movements makes the ataxia worse, and lets it appear in patients even who perform their movements in a normal manner as long as they can control their movements with the eye. The change that comes over the movements when the ocular control by the patient is withdrawn is a valuable diagnostic sign, by means of which we can distinguish between tabetic and cerebral or cerebellar ataxia. In the latter conditions the movements undergo no modifications when the eyes of the patient are shut, and the patients are able with their eyes shut to walk almost as well as when they are looking on.

In those diseases of the nervous system in which the motor disorder

consists of a mixture of genuine ataxia and of a tumbling, swaying movement, it is possible by means of the eye test to determine whether and to what degree the ataxia is similar to that in tabes. In Friedreich's hereditary ataxia the "cerebellar" prevails over the purely ataxic gait; even in advanced cases the patients are able to walk with their eyes shut, a thing of impossibility with the tabetic. If the patients are made to undergo the usual tests for ataxia, they mostly shew quite insignificant lesions. In this manner it might be possible to distinguish between the motor disorder which is connected with lesions in the posterior columns of the spinal cord, and that whose cause must be looked for in the cerebellum. The test might be also useful in some of those difficult cases where we have to decide between Friedreich's ataxia and juvenile tabes.

One of the commonest symptoms of tabes is the more or less pronounced inability of the patients to keep their balance while standing. The so-called Rhomberg's phenomenon is one symptom of this loss of balance. If the patients shut their eyes while they are standing, even slight loss of the equilibrium may be observed. To keep one's balance when standing on so narrow a base as is furnished by both feet put together demands the exact and harmonious co-operation of all the muscles of the body. Static ataxia is only one of the many ataxic symptoms of the tabetic, subject to the same laws and capable of the same explanation as the rest of the tabetic symptoms. Rhomberg's phenomenon is considered an initial symptom of tabes, because the preservation of the equilibrium on standing with the feet in apposition and the eyes closed is one of the most difficult functions of coordination, and must therefore be one of the first that are impaired.

Those patients who shew Rhomberg's sign, but none of the other motor anomalies, cannot rightly be said to be still in the pre-ataxic state, unless it be entirely due to anæsthesia of the soles of the feet, which is a very rare occurrence; on the other hand, the presence of Rhomberg's sign must invite to look for other symptoms of ataxia. Whenever Rhomberg's sign is found, other ataxic symptoms are also present; the so-called pre-ataxic stage is much rarer than one would expect. In advanced cases the patients begin to sway to and fro, even if they have their eyes open, as soon as they look away from their feet. We have seen patients whose bodies shewed the characteristic swaying when they were sitting without leaning against the back of the chair.

Besides Rhomberg's sign, there are other modifications of the

faculty of keeping the balance which may be found in tabetic persons even at so early a stage that neither walking nor the other ordinary movements of everyday life seem to be interfered with, and the patient when examined in bed executes all movements most correctly.

Many tabetic patients can balance themselves very well on one leg, but if we examine them a little more closely we find that they hold the other leg flexed in a manner which is different from that observed in healthy people. Fig. 36 shews how tabetic subjects hold the raised leg. The thigh is slightly flexed in the hip-joint, whereas the leg forms an acute angle with the thigh. The foot is held parallel to that on the other side. A healthy subject instinctively will take up quite a different attitude when he is asked to stand on one leg (Fig. 35). He will flex the thigh in the hip-joint until it is at a right angle with the perpendicular axis of the body, but the leg will be bent to a much less degree, so that it forms a right, or even an obtuse, angle with the thigh. The leg will thus be almost parallel to the other leg, and the toes will not point downward, as in Fig. 36, but forward. Another abnormality may be seen when patients are asked to bend their knees without support (Fig. 2). A healthy subject will instinctively hold himself erect while executing this movement, or bend forward to a very small extent while the thighs are abducted and the heels lifted off the ground (Fig. 1). The tabetic patient, on the other hand, bends his body forward excessively and holds his thighs in adduction; his attitude is that of a person who wants to sit down on a chair. The attitudes shewn in Fig. 2 and Fig. 36 appear to an observer much more difficult than the manner in which healthy subjects perform these movements; the patient, therefore, must have some very cogent reasons for doing otherwise. In Fig. 36 the patient bends the leg upon the thigh *ad maximum;* extreme flexion is the easiest position of a joint for a tabetic, because it allows him to use, instead of the graduated coordinate contractions of muscles, the

Fig. 1.—Normal Bending the Knees.

maximum of motor innervation. When the leg has been flexed upon the thigh, it forms one piece with the thigh, as it were, the balance will be more easily kept, and the patient has to direct his attention to one limb only instead of two. The same may be said of Fig. 2. Here again is the manner in which the patient bends his legs characterized by the smallness of the angles between body and thigh

Fig. 2.

on the one hand, and thigh and leg on the other. For a very potent reason the patient places his centre of gravity differently from a healthy subject. We therefore observe, besides motor ataxia in voluntary movements and static ataxia in trying to keep the balance when standing erect, a third change in the functions of the muscular system, an abnormally situated centre of gravity. This anomaly appears early in the course of the disease, much earlier than the rest of the ataxic symptoms, and is characterized by the fact that the

muscular system can perform any task that is set for it, but will do so in a manner other than that observed in a healthy person. Later on we shall see whether all anomalies of posture and movement that are observed in tabetic persons belong to the same category as ataxia, and whether they all have the same origin and development.

MUSCULAR HYPOTONIA IN TABES.

One of the most important details in the clinical picture of locomotor ataxia is the intactness of the muscular system. The muscular strength, as such, remains unimpaired, no matter how great is the loss of coordination and the motor disturbance resulting therefrom. In some cases of locomotor ataxia one finds atrophy or paresis of one or more muscles; but these changes must be considered to be complications which have no causal connection with the morbid process of tabes.

Some clinical observers have drawn attention to a symptom which they observed in examining the muscular system of tabetics, and which they described as a diminution of the muscular tone without alteration of the muscular strength. Leyden, in his publication on "The Grey Degeneration of the Posterior Columns of the Spinal Cord" (1863), wrote: "Since the experiments of Cohnstein and Brondgeest, it must be considered probable that the muscles are in a state of slight contraction, which we call tone—that is, dependent on the integrity of the posterior (sensitive) spinal roots; that this tone disappears after section of these roots, and that therefore the muscular tone must be considerably impaired when the posterior roots become diseased and atrophic, and the permanent reflex stimulation of the sensitive nerve-endings abolished. There can be no doubt that the relaxation of the muscles and the abnormal mobility of the joints of the extremities is a direct consequence of the partial or total abolition of the muscle tone. The muscles do not check one another; there is no harmony in the play of the antagonists; the limbs are thrown about in an apparently aimless fashion. It is more than probable that at least some of the disturbances to which the sphincters of the bladder and rectum are subject are due to this want of harmony on the part of the antagonists."

Lately Achard and Debove have examined the sound produced by the contraction of the muscles, and they have found that in tabes this muscular sound is materially altered; they based on this alteration of the muscle sound in tabes a new theory of ataxia. In 1896 we

described a peculiar symptom which we believed to be caused by the diminution of the muscular tone, and proposed to call it "hypotonia." This muscular hypotonia enables tabetics to execute movements which healthy subjects could never perform, such as raising the stretched lower limb, a movement which healthy subjects can perform only to a very limited extent; some tabetic patients can lift the limb with extended knee so high that it almost touches the face (Figs. 8 and 9).

The interest which attaches to this peculiar symptom is enhanced by the fact that it is met with in all tabetic patients. At first one thought that this hypotonia was only characteristic of advanced cases and of sporadic occurrence in the initial and early stages of tabes. Experience has enabled us to recognise even slight degrees of this anomaly in every case of tabes, and we have come to the conclusion that this hypotonia does not necessarily befall in like degree all muscle groups of the lower limb, but that it picks out certain groups, like those about the knee-joint, leaving others, like the muscles of the hip, comparatively untouched. Muscular hypotonia, as a symptom of tabes is seldom absent, and may be met with in the early stage of the disease, long before the first manifestations of ataxia are noticed. Further interest is lent to this peculiar symptom by the fact that it is even found in patients whose muscular system in a state of rest does not shew the slightest change on inspection or palpation. It is true that, especially in advanced cases of tabes, one finds the muscular system badly developed and flabby, but we have seen extreme degrees of hypotonia in patients with excellent muscles and a very high amount of muscular tone, and also patients with wasted, flabby muscles and a very moderate amount of hypotonia.

The expression "flabbiness," though descriptive of the state of nutrition of the muscles of some cachectic tabes patients, cannot be used for the purpose of differential diagnosis, for it is impossible to define accurately various degrees of flabbiness. The condition of the muscular system, however, for which we propose the word "hypotonia" can be accurately measured, as we shall shew later on. The chief characteristic of hypotonia is the diminution or entire abolition of the power of checking certain movements. The importance of this pathological change for the clinical description of tabes lies in the possibility of demonstrating and measuring it. The difference, for instance, that exists between the manner in which healthy and tabetic subjects raise their extended lower limbs is a symptom of great physiological importance, and has, as far as we know, not yet received the attention it deserves. We learn from it that there are groups of

muscles which fulfil the same task as the osseous and ligamentous parts of a joint, namely, that of stopping a movement which has a tendency of continuing beyond a previously-fixed maximum. Here we have not passive movements which are made possible by the

Fig. 3.—Healthy Subject: Maximum Flexion of Thigh and Knee.

reduced sensation of pain that characterizes the tabetic, but voluntary active movements which the tabetic can perform because of the absence of all checking power.

Inspection and palpation of the muscles generally do not give

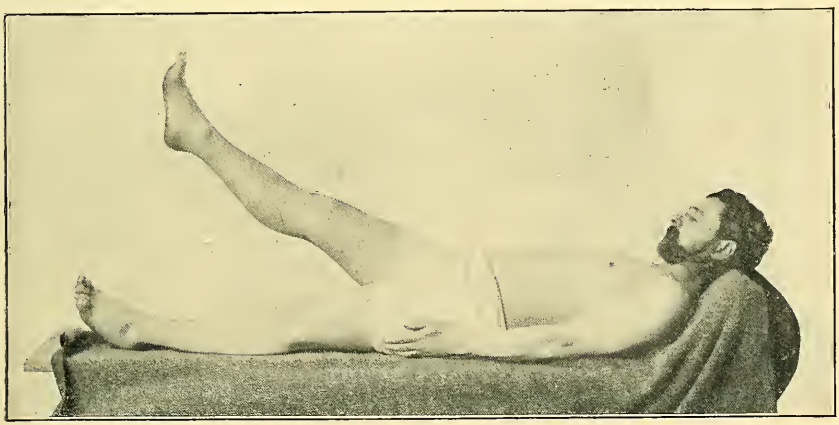

Fig. 4.—Healthy Subject: Maximum Flexion of the Thigh with the Knee extended.

sufficient information regarding muscular hypotonia. Each functional unit of muscles must be separately examined. For those flexor muscles which are inserted on the pelvis and the leg, and which act also as extensors of the pelvis, the characteristic sign of hypotonia is the following: The lower limb, with knee extended, so that leg and

thigh are in a straight line, can be raised more or less high; *i.e.*, it can be flexed upon the pelvis. A healthy subject who tries to flex the thigh upon the pelvis when lying on his back cannot do this without

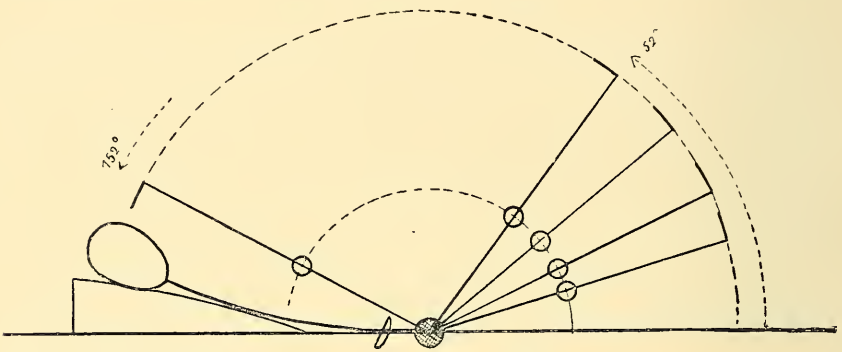

Fig. 5.—Diagram representing Positions of the Lower Limb with the Knee extended.

bending the leg as soon as the thigh has been raised an angle of about 30 to 50 degrees (Fig. 4). The more the thigh is flexed upon the pelvis, the greater is the flexion of the leg upon the thigh (Fig. 3).

Fig. 6.—Moderate Hypotonia of Flexor Muscle of the Leg.

What is the reason for this inability of healthy persons to keep the knee extended when flexing the thigh beyond an angle of 45 degrees? It cannot be an impediment of a ligamentous or osseous nature, for

when the knee is bent we can flex the thigh upon the pelvis to upwards of 120 degrees (Fig. 5). The only check which is exercised on the flexion in the hip-joint of the extended lower limb is produced by the group of flexor muscles which at the back of the thigh run from

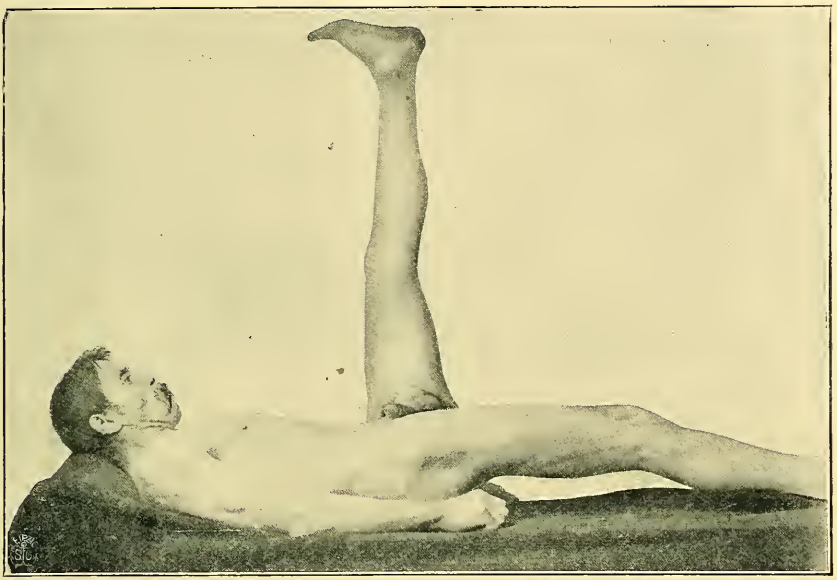

Fig. 7.—Moderate Hypotonia of Flexors of Leg.

Fig. 8.—Extreme Hypotonia of Flexors of Leg.

the pelvis to the leg. If the extended limb can be raised to an angle of 60 to 100 degrees and more, as is frequently the case in tabes, then the flexors of the thigh (semitendinosus, semimembranosus and biceps muscles) must have undergone an alteration of their function, and

this alteration we call hypotonia. In advanced cases of tabes this hypotonia may become so excessive that the toes can almost be made to touch the face (Figs. 8 and 9). Slighter degrees (Figs. 6, 7, 10, 11) will always be found in tabetics.

Fig. 9.—Extreme Hypotonia of Flexors of Leg.

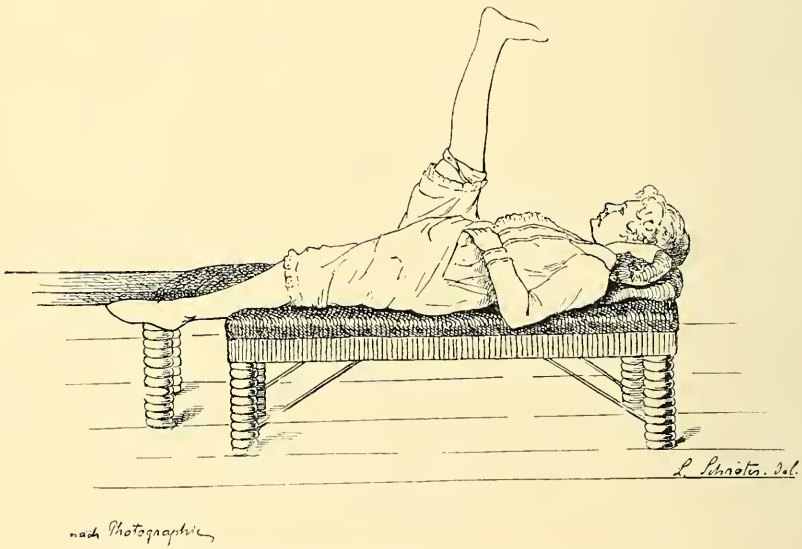

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Fig. 10.—Moderate Hypotonia of Flexors of Leg.

The existence of a hypotonic condition of the muscles in front of the thigh, *i.e.*, of the extensors of the leg, can be ascertained if in the horizontal position the thigh be flexed upon the pelvis at the same

time as the leg is flexed upon the thigh. In healthy subjects a point is soon reached when further approximation of the leg and thigh becomes impossible. The check is here exercised by the quadriceps

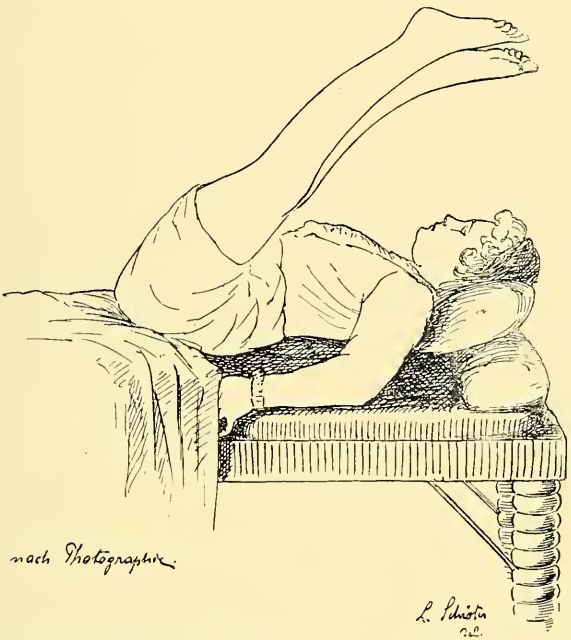

Fig. 11.—Marked Degree of Hypotonia of Flexors of Leg.

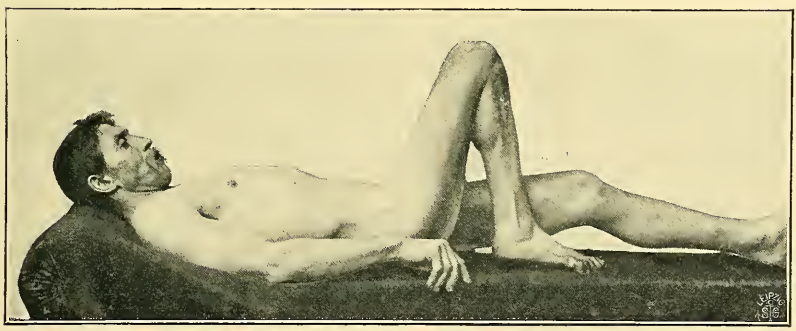

Fig. 12.—Moderate Hypotonia of Quadriceps.

cruris and the patella. In tabetic subjects the whole length of the leg can often be brought into direct apposition to the thigh, so that the heel rests upon it. Hence the degree of hypotonia of the

quadriceps can be measured by the angle between leg and thigh, or in centimetres by the distance between the heel and tuber ischii (Fig. 12). In examining the hypotonia of the adductor muscles

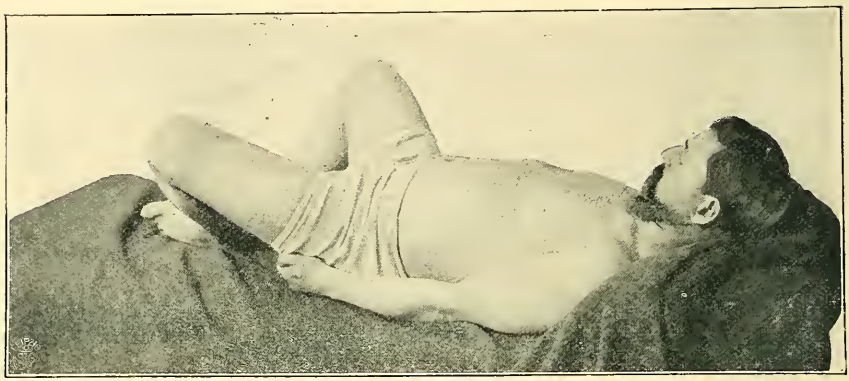

Fig. 13.—Examination for Hypotonia of Adductors (Normal).

of the thigh, the thigh is moderately flexed upon the pelvis and then *ad maximum* abducted; that is, one tries to press the flexed thigh outwards and downwards. Under normal conditions there will

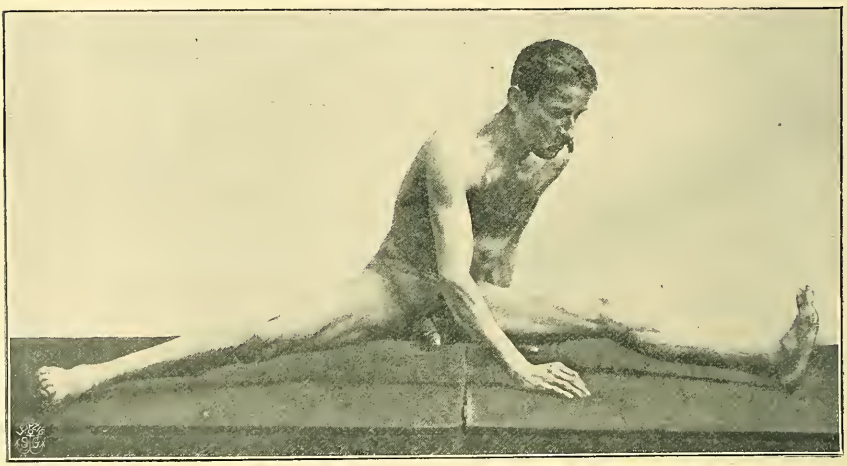

Fig. 14.—Marked Hypotonia of Adductors of the Thigh.

always remain a considerable distance between the knee and the couch on which the person rests (Fig. 13). The greater the hypotonic condition, the more will the knee approach the couch, until in advanced cases the knee actually rests on it. In such cases the thigh, which is

kept flexed in abduction, rests with its whole length upon the couch. In advanced cases of hypotonia of the adductor muscles with consecutive relaxation of the joints, positions are possible like the one depicted in Fig. 14.

As regards the muscles of the leg, the group first to be considered is that which connects the tendo Achillis with the lower end of the femur. We have seen when the thigh is being flexed upon the pelvis that the biceps group at the back of the femur fixes the knee in a flexed position; similarly, the tendo Achillis (group of gemelli muscles) is responsible for that slight flexion of the knee which is nearly always observable in persons who are standing (Fig. 22*b*). When the

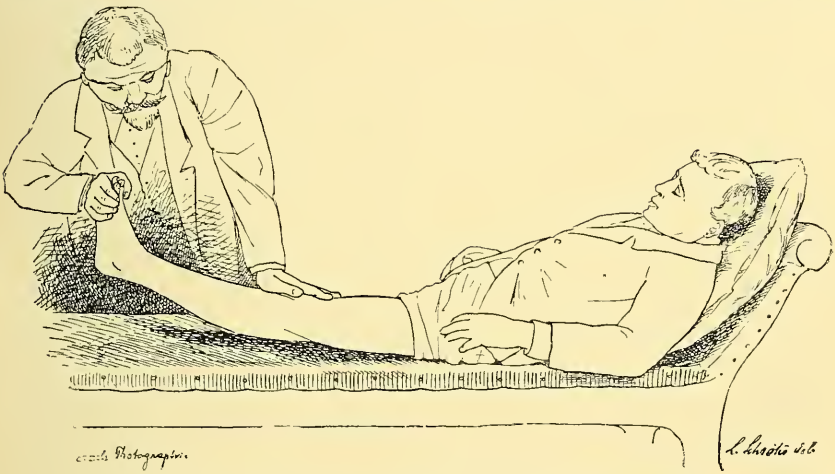

Fig. 15.—Large Degree of Hypotonia of Flexors of Leg.

normal function of the tendo Achillis is impaired, the knee-joint can be hyperextended. Thus, if the patient lies down so that the whole length of the thigh rests on the couch, the leg can be lifted off the couch for a short distance. The distance between the heel and the couch can be measured in centimetres, and gives the exact degree of hypotonia of the muscles at the back of the leg (Fig. 16).

The result of the hypotonia of the muscles of the leg which are situated in front is abnormal mobility of the foot in the ankle-joint, which often causes tabetics to sprain their ankle. This flail-like condition of the ankle-joint is easily demonstrable in tabetics (Fig. 17).

When the hyperextension of the knee-joint was described, we discussed the question whether this anomalous condition was caused by changes in the structure of the ligaments and the capsule or by

changes in the muscles. The same question arises now with regard to the ankle-joint. When we demonstrated the hypotonic condition

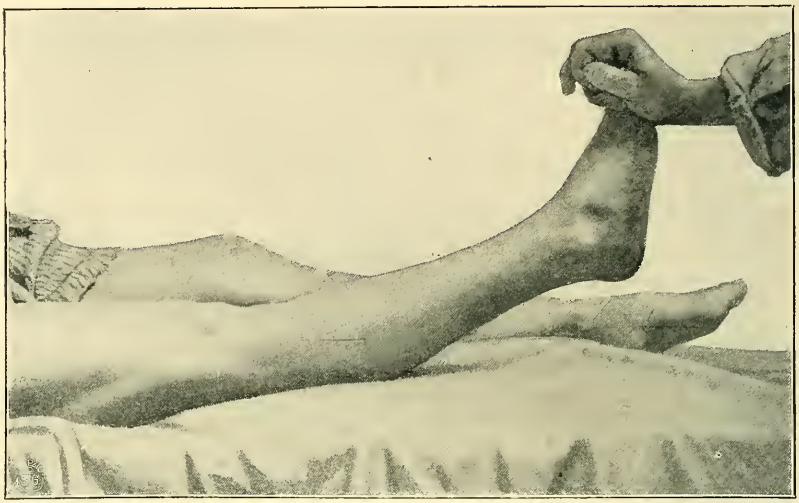

Fig. 16.—Hypotonia of Flexors of Leg.

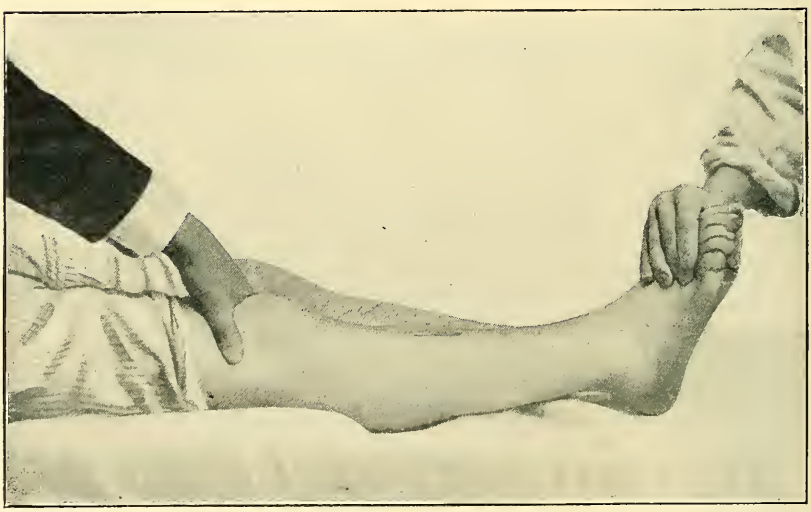

Fig. 16a.—Examination for Hypotonia of Flexors of Leg (Normal).

of the flexor muscles of the leg, we shewed that the capsule and the ligaments cannot have a share in producing the abnormal mobility of the leg, as this looseness becomes visible only when the knee-joint is

extended. There can be no doubt, therefore, that we have to deal with a modification of the muscles themselves. As regards the adductor muscles of the thigh, it is easy to prove that in healthy subjects the tendons at their insertion on the os pubis become very prominent as soon as the thighs are forcibly abducted. In tabetic patients this tension of the adductor tendons is absent. This is sufficient evidence that the muscle substance itself has undergone an

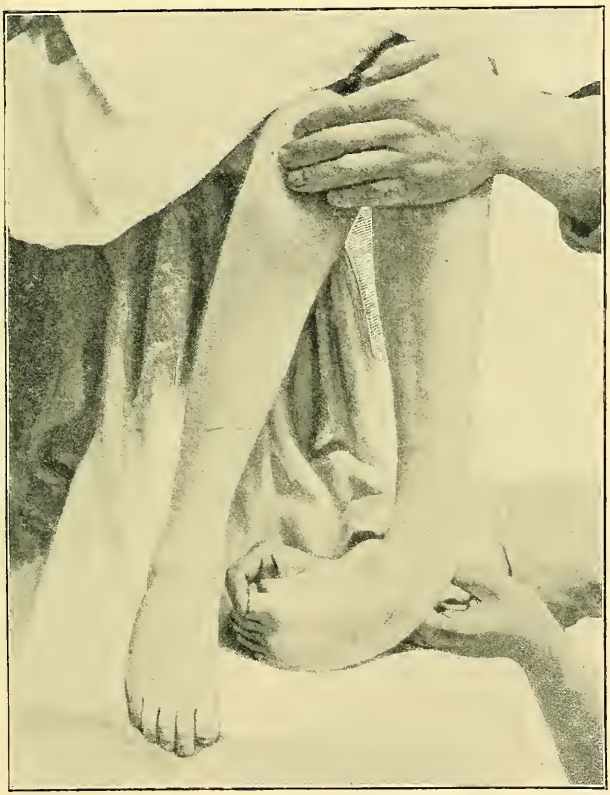

Fig. 17.—Abnormal Mobility in Ankle-joint.

alteration. Experiments on the dead body confirm the view that the above-described abnormal mobility of the joints is due to changes in the substance of the muscles, and not in that of the articulations and ligaments. Immediately after death the body is so pliable that one can imitate all the abnormal positions of the limbs that we have observed in tabes. It is obvious that there we cannot put this pliability down to pathological changes in the articulations and ligaments. On the

other hand, there cannot be any doubt that the preservation of the normal shape and elasticity of the capsules and ligaments of a joint *depends on the normal function of the muscles which are inserted in its neighbourhood.* A joint whose muscles do not act at all, or only with impaired tone, cannot render proper resistance to the blood and lymphatic current nor its own gravitation, and so must pass into a state of relaxation. In cases of infantile polio-myelitis anterior and of peripheral paralysis, one finds more or less flail-like joints. Secondary changes in the ligamentous apparatus of the joints, produced by want of muscular tone, and by the pull and pressure exercised by the body, are not at all rare in tabes. The same may be said of the fasciæ and aponeuroses, which are kept at a proper state of tension by the action of the muscles. The knee-joint is specially predisposed to such changes,

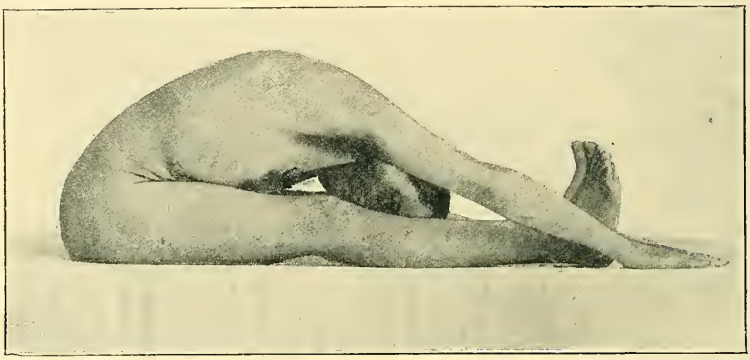

Fig. 18.—Hypotonia of the Muscles of the Pelvis and Spinal Column.

because the weight of the whole body rests on it; sometimes such excessive degrees of hyperextension are produced that thigh and leg form a re-entering angle in front (Fig. 24). Of course, we speak here only of cases in which no arthropathic condition can be found.

Changes in the normal movements of the vertebral column enable tabetic persons, when sitting with their limbs stretched out horizontally, to bend their body forward to such a degree that sometimes their face rests between their legs on the couch (Fig. 18). This abnormal flexibility of the back has its origin in a hypotonic condition of those muscles which extend from the pelvis to the lower limb, in an increase of laxity of the capsule of the hip-joint, and in an exaggeration of the flexibility of the spinal column itself.

In the upper extremities the consequences of hypotonia of the muscles can be demonstrated in the fasciæ and joints. When the upper limb has been affected to a very great degree the fingers can

easily be distorted and brought into the most ridiculous positions (Fig. 19). Hypotonia of the flexor group which runs from the forearm to the palm sometimes permits of so much hyperextension of the fingers that they stand at right angles to the back of the hand.

In rarer cases hyperextension is possible in the elbow and shoulder joints, where likewise the movement of extension is checked only by impediments of an osseous nature. A short time ago we had an opportunity of examining a patient who shewed a curious peculiarity

Fig. 19.—Hypotonia of Hand and Fingers.

of the spinal column which we had never before seen, and which probably belonged to the same class of case. A medical man, sixty-five years old, had for upwards of ten years had lancinating pains, contraction of the pupils, absence of patellar reflexes; until the last five years walking was not interfered with; there was at no time marked ataxia of the lower limbs. In the course of the last five years the patient acquired a peculiar prominence of the vertebral spines in the lumbar region, combined with a feeling of discomfort and weakness in sitting and standing. In consequence of it the upright position and

walking were almost entirely abandoned; the patient developed a habit of leaning forward when sitting; in bed his back was supported by pillows in a half-sitting position. Gradually it became difficult and painful to sit up, and the patient kept to his bed. The clinical examination shewed all the cardinal symptoms of tabes. In bed there was very little ataxia and loss of sensation of passive movements noticed; the muscular strength was not impaired, and there was only a slight degree of hypotonia; yet the patient was quite unable to

Fig. 20.—Hypotonia of the Flexors of the Hand and Fingers.

walk, or even change his position in bed without being supported. When the patient was supported under both arms and told to walk across the room, his body was bent forward to such a degree that it was almost in a horizontal position; the patient reminded one of a case of paralysis agitans. He could not stand upright. When the patient was lifted up by the shoulders so that his toes just touched the ground, his back became straight at once; it also became straight when the patient was lying down on his back without pillows. The patient felt no pain in this position, but only a slight sensation of

tension in the abdominal muscles. The abdomen on palpation shewed that the flanks were both soft, but the recti muscles were very prominent and remarkably tense. This tension became less when the patient was brought into the sitting position. The muscles of the back were found absolutely normal as far as their strength was concerned. When the patient was sitting up three or four lumbar vertebræ were so prominent that they formed a veritable gippus; the spinal column looked like kinked. We have already stated that this anomaly disappeared when the patient was being suspended or was lying down; therefore it can only be due to the weight of the body pressing on the spinal column; there was no affection of the spinal column, nor muscular paresis, for his muscular strength was quite intact. If, however, we suppose that there was hypotonia of the short erector spinæ muscles at the back, with consequent relaxation of the ligaments, then we can understand why the vertebræ become prominent only when the weight of the body rests upon them. In consequence of the patient's habit for many years of bending forward, he had acquired, from mere inactivity, a permanent shortening of the recti abdominis muscles; these muscles, in turn, had made the erection of the spinal column at first difficult, and ultimately impossible. Such contractions of muscles, in consequence of the inactivity of their antagonists, are of frequent occurrence in tabetics who are confined to bed. Of what eminently practical importance is the detailed examination of the muscular system of tabetic patients has been shewn in this case; for it was not ataxia in the lower limbs, as his doctors had thought, that deprived this patient of his power of walking, but solely the anomalous condition of the muscles which we have just described. With a suitable apparatus the patient should be able to commence walking again.

Slight degrees of hypotonia of the abdominal muscles are frequently found; we have also seen cases in which the hypotonic condition of the abdominal muscles was such that it was quite impossible to feel any muscle at all; the intestines seemed to lie immediately under the skin, and there was marked abdominal ptosis.

These pathological changes in the muscles are absolutely pathognomonic for tabes dorsalis. We have found general, or almost general, hypotonia only in cases of tabes where the symptoms were such that there was no doubt as to the correctness of the diagnosis. The peculiar habit and gait which result from muscular hypotonia are so characteristic that one can diagnose the disease from this symptom alone. It is, further, beyond doubt that slight degrees of hypotonia

may be found in the initial, *i.e.*, pre-ataxic, stage of tabes. We may therefore consider hypotonia an initial symptom of tabes. Contracted pupils, absence of patellar reflexes, and hypotonia of all or most of the muscles of the lower limb, are often present in cases in which ataxia has not yet developed.

Besides in tabes, severe typical hypotonia of almost the whole muscular system may be found in cases of congenital cerebral affections in children who do not exhibit the typical symptom complex of Friedreich's ataxia. In these cases one may find strabismus, nystagmus, ataxia of a peculiar cerebellar kind when lying down, without changing when the eyes are closed, and without the exaggerated excursions which give the movements of tabetics a curious "throwing" or "thrusting" character. There is no paresis and no trace of any loss of cutaneous or articular sensibility.

As the only real criteria of hypotonia consist in peculiar active and passive movements which healthy subjects cannot execute at all, the question arises whether persons whose profession necessitates the performance of excessive movements. such as acrobats, dancers, etc., become able, through practice and education of their muscles, to perform movements which are analogous to those observed in hypotonic persons. As far as I have been able to judge from examining such persons, this analogy is very slight. Only in those who have performed as acrobats or dancers since their early childhood has such a degree of systematic extension of the muscles and ligaments been produced that the amplitude of their muscular movements equals that of tabetic subjects. I had occasion to examine an English dancer who since her twelfth year had practised extending her muscles and joints. This lady was indeed able, not only in prone, but also in sitting position, to raise her lower limb with extended knee so high that it touched her face. She could keep the limb in this position apparently without special effort. As regards the other groups of muscles, she could with the adductors of the thigh and the quadriceps perform movements which we have learnt to regard as characteristic of the hypotonia of those muscles. In this case we have to do with an actual elongation of the muscles, which was produced by systematic hyperextension of the muscles while they were still growing. In walking and standing the lower limbs shewed no semblance to the hypotonic condition of tabetic subjects, but appeared to be perfectly normal as regards the muscular and ligamentous tone.

The causes of tabetic hypotonia have been sought for in the loss of the nerve stimuli which the cells of the anterior horns receive from

BOSTON MEDICAL
FEB 24 1903

the posterior columns. The present state of our knowledge, however, does not enable us to accept the theory of the reflex origin of the muscle tone as settled. The fact that often there is no apparent relationship between the loss of sensibility and the muscular hypotonia proves that there must be one or more links missing in the chain of evidence. Further, the question becomes still more complicated by the fact which we have observed in a number of cases—that marked, nay, even advanced, degrees of hypotonia may exist side by side with more or less exaggerated tendon reflexes. So had the patient with congenital cerebellar disease on one occasion exceedingly brisk tendon reflexes. Whatever may be the cause of tabetic hypotonia, one thing is certain, namely, that *hypotonia of a muscle group does not abolish the tendon reflexes of the muscles.*

Some authors have endeavoured to establish a relationship between the muscular tone and ataxia. In all cases of ataxia one finds the muscular tone diminished; yet one cannot, in the absence of all parallelism between both phenomena, support the view that ataxia is caused by the loss of muscular tone. Although severe ataxia and entire absence of hypotonia will scarcely ever be met with, considering that both are symptoms belonging to an advanced state of the disease, there certainly are cases where hypotonia exists without a trace of ataxia. *Ataxia, therefore, cannot be caused by loss of muscle tone,* but there is no doubt but that the ataxia, when combined with hypotonia, especially in an advanced state, presents a different aspect than where it exists uncomplicated by hypotonia. The following example will serve to illustrate our point. A tabetic patient lying on a couch or in bed during examination shews scarcely a trace of ataxia; the sensibility of his joints and muscles is almost unimpaired: we should therefore expect that the patient would be able to walk without difficulty. But this is not the case. We see that the patient walks with difficulty, and scarcely manages to keep himself from falling by leaning heavily on a stick. Yet the strength of his muscles is everywhere normal. He suffers from a very severe degree of hypotonia of the muscles of the knee and hip-joint; his thighs are rotated outwards; the knee-joints are hyperextended in a manner which one finds only in hypotonic cases of tabes; hence the characteristic "frontal" position of the feet which disturbs the equilibrium of the whole body, so that the trunk must be bent forward to compensate the position of the lower limbs. The absence of the normal flexion of the limb in the knee-joint completely alters the manner of walking, etc. How shall we call this gait? Ataxic, of course, for we have no other term

for it, and because we habitually call ataxic in tabes all motor disturbances if paresis and arthropathic changes are absent. The fact that, in spite of only slight loss of sensibility, we find such considerable impairment of locomotion proves the enormous importance which hypotonia possesses among the clinical symptoms of tabes, and I have no doubt that the perfectly legitimate resistance that some prominent neurologists have offered against the theory which explains ataxia by the loss of sensation would have been removed if the modifying influence exercised by the hypotonia on the amount and type of ataxia had in each case of tabetic ataxia been thoroughly understood. Those instances of the apparent incongruence between the intensity of the loss of sensation and of ataxia would thus have received a satisfactory explanation.

If the muscular tone is a reflex, hypotonia must necessarily be

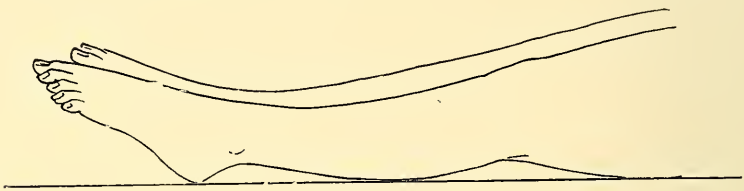

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Fig. 21.—Hypotonic Pseudo-Paresis; Muscular Strength Normal.

brought into connection with changes in the centripetal parts of the spinal cord. A more precise localization is as yet impossible. We know that the spinal reflexes are not all dependent on the same organ: muscle tone, cutaneous and tendon reflexes, may, as we now know, be affected differently and independently of one another. There is no direct relationship between the loss of muscular sensibility and muscular hypotonia. We have seen, further, that when this symptom is a constant companion of tabes dorsalis that it is also found in cerebellar, and most probably also quadrigeminal, disorders. For the present we must be satisfied with the belief that hypotonia is produced by a morbid change in certain reflex mechanisms which in their turn are influenced by centres situated higher up in the central nervous system.

The symptoms of hypotonia become prominent only during active or passive movements, but there are other anomalies of the muscles in tabes which are visible while the limbs are at rest. The muscles of tabetic patients have a tendency of very imperfectly resisting the

weight of the limbs. One of the most common instances of this tendency is presented by the position of the feet in dorsal flexion, although there is no loss of muscular strength. The rotation of the

FIG. 22A. — ALTERATION OF POSTURE IN CONSEQUENCE OF HYPOTONIA OF THE KNEE-JOINT.

FIG. 22B.—NORMAL POSTURE.

thighs outwards to such a degree that the whole length of the outer edge of the foot rests upon the couch, the tendency when sitting to let the knees fall outwards, are other examples of this very frequent

symptom. In healthy persons one never finds these conditions, and it is probable that they are only another expression of hypotonia. In cases of tabetic paresis of the abducens muscles the eye is fixed in a position which does not correspond to the intensity of the paresis; even when the paresis of the abducens muscle is only very slight, the eye is frequently rotated inward much beyond the middle line of the orbit, although voluntary outward rotation has only slightly been impaired. This peculiar and not infrequent symptom may have its origin in a hypotonic condition of the external rectus muscle, in consequence of which the internal rectus is able to pull the eye over to its side. It is a moot point whether the paresis of the vocal cords which is often noticed during the initial stage of tabes is due to hypotonia of certain laryngeal muscles or not. The following case furnished an interesting example of this kind: A town-crier who suffered from incipient tabes dorsalis was much troubled by difficulty of breathing, which was caused by changes in the muscles of the glottis. His breathing became so bad that tracheotomy had to be performed; yet the muscles of the larynx followed promptly the voluntary impulses of the patient, who could shout and speak with a loud voice as his profession demanded, in spite of this impediment to respiration. With regard to the bladder troubles of the tabetic, it is impossible, of course, to distinguish whether they are caused by loss of sensibility or by hypotonia, or by both. That here, too, reflexes have been lost is out of the question, but we cannot, in the absence of positive proof, accept the theory that the bladder troubles are the consequence of a lesion of motor centres in the spinal cord.

THE INFLUENCE OF HYPOTONIA ON THE ATTITUDE OF THE BODY.

The modification of the erect attitude of the body in consequence of the loss of muscular tone, is produced by the resulting pliancy of the joints. The outward rotation of the thighs has a greater effect on the erect attitude than the inward rotation; but the greatest influence is exercised by the hyperextension of the knees and the changes that take place in the ligaments of the spinal column. We know that the maintenance of the equilibrium of the body in the erect attitude is chiefly the function of the trunk. Any change in the position of the lower limbs is accompanied by a corresponding change in the attitude of the trunk. It is therefore obvious that any change

FIG. 23.—MARKED HYPOTONIA OF THE KNEE-JOINTS; MORE OBVIOUS ON THE RIGHT SIDE.

FIG. 24.—THE SAME, SEEN FROM THE RIGHT SIDE.

FIG. 25.—MODERATE DEGREE OF HYPOTONIA OF THE KNEE-JOINTS.

FIG. 26.—MODERATE DEGREE OF HYPOTONIA OF THE KNEE-JOINTS.

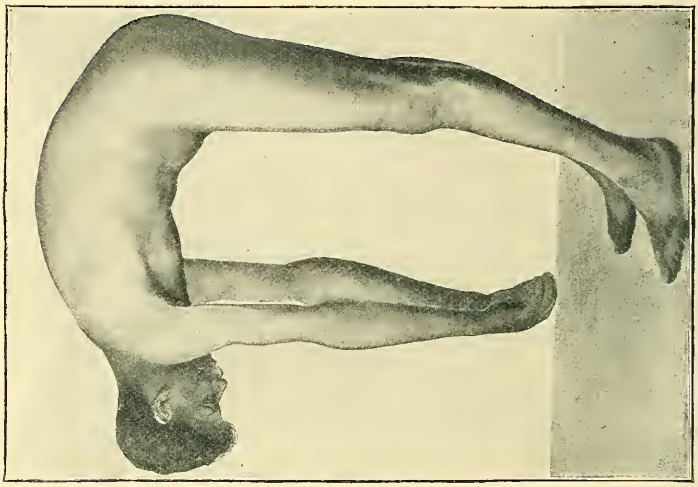

Fig. 28.—Moderate Degree of Hypotonia of the Hip-joints.

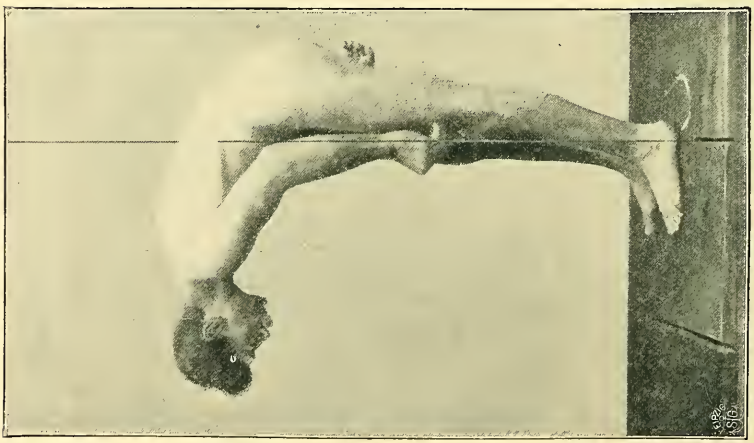

Fig. 27.—Slight Degree of Hypotonia of the Trunk.

from the normal slightly flexed condition of the knee-joint to a state of extension must be followed by a bending forward of the trunk, in order to maintain the equilibrium. Figs. 22A, 23, 25, 26 give a very good idea of the influence of the knee-joint on the erect attitude.

Figs. 23 and 24, which refer to one and the same patient, shew that the changes need not necessarily attack both knees to the same degree. The most advanced states of hypotonia of the knee-joint are of course accompanied by a corresponding change in the attitude of the trunk (Fig. 24). These static changes naturally become more prominent when the patients try to walk, for not only do the lower limbs lose their stability in consequence of the pliancy of the joints, but the trunk has to be forced into most awkward positions in order to maintain the disturbed equilibrium. This intimate relationship between a hypotonic condition of the knee-joints and the attitude of the trunk explains why, in one and the same patient, one very often finds a relatively slight amount of ataxia while he is lying down, give way to great difficulty of locomotion as soon as he tries to walk by himself. Hypotonia of the hip-joints allows of excessive bending-forward movements of the trunk (Figs. 27, 28, 29). Fig. 29 shews that a very advanced state of hypotonia of the hip-joint may be accompanied by a very moderate hypotonia of the knees.

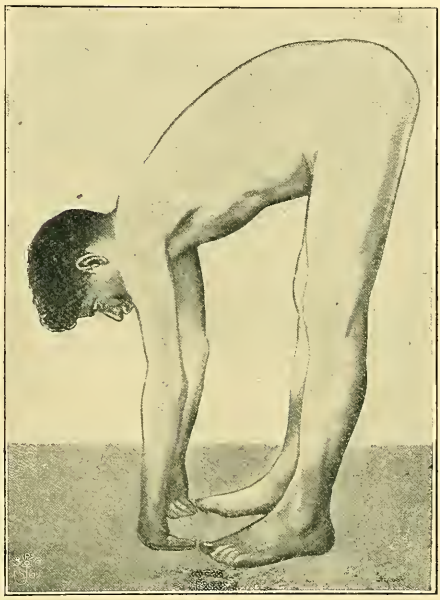

Fig. 29.—Advanced State of Hypotonia of the Hip-joints.

THE IMPORTANCE OF HYPOTONIA FROM THE POINT OF DIFFERENTIAL DIAGNOSIS.

There is no doubt that all stages of tabes may be complicated by muscular hypotonia. The intensity and extent of hypotonia is not in direct proportion to the loss of sensation or coordination, although

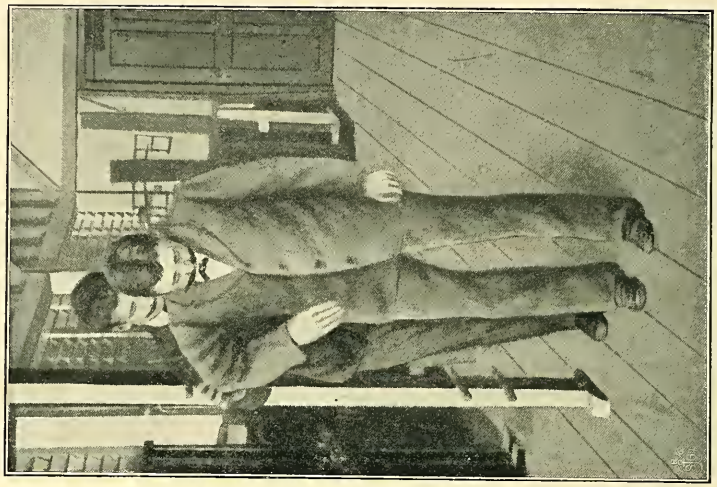

Fig. 31.—Hypotonic Inward Rotation of the Thigh.

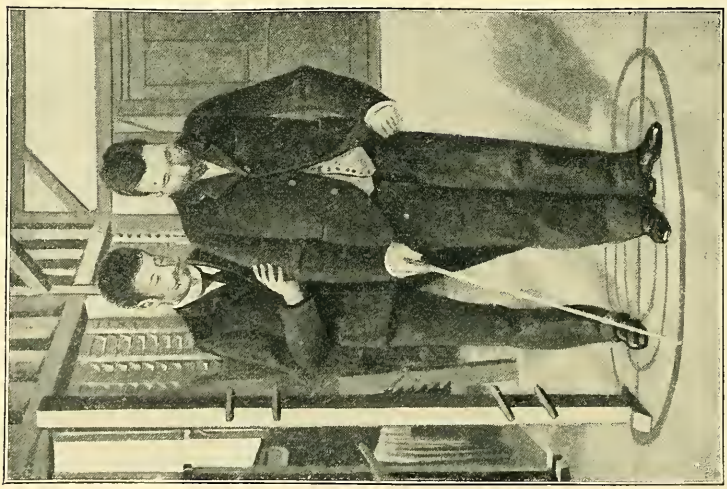

Fig. 30.—Hypotonic Outward Rotation of the Left Lower Limb.

it may be generally correct to say that severe hypotonia is in most cases combined with severe loss of coordination. With the exception of cases of tabes dorsalis, the author has met with severe universal muscular hypotonia only in cases of congenital malformation of the cerebellum. In the cases of congenital cerebellar malformation which came to the notice of the author, he found general muscular hypotonia, but the muscular strength and sensibility was intact, and there was present a kind of motor disturbance which is sometimes confounded with tabetic ataxia, but which differs from it in every detail, such as staggering movements which are not influenced by closing the eyes, and so on. The tendon reflexes are sometimes exaggerated, sometimes normal, or even absent. In Friedreich's ataxia, in the purest types of which one never misses loss of cutaneous sensibility and orientation, the diminution of the muscular tone was much less marked than in the cerebellar affections mentioned above.

Fig. 130 shews a boy, ten years old, who in standing exhibits all characteristic symptoms of muscular hypotonia. He was enabled to stand by himself only after some orthopædic appliance had been made for him (Fig. 131). A lesser degree of hypotonia was found in a case of syringo-myelia with tabetic symptoms, and in a case of tubercle of the corpus quadrigeminum (autopsy). In cases of cerebral disease or of peripheral neuritis with complete atrophy of the muscles, however, hypotonia could not be detected after the *restitution of the muscles had commenced;* nor could it be found in other chronic systemic affections of the spinal cord. It is doubtful whether muscular hypotonia is present in transverse lesions of the cord. Muscular hypotonia is a constant symptom of tabes, and serves to recognise the early stage of the disease, as well as to differentiate between it and other affections, like peripheral neuritis, hysteria, etc. Anatomically, hypotonia must be connected with lesions of the centripetal organs of the spinal cord, or the large ganglia of the brain and cerebellum, but it has not yet been possible to localize the seat of the lesion. Its independence from the loss of sensation and the tendon reflexes does not allow us to consider it to be the result of a lesion in one of the reflex arcs.

THE RELATION BETWEEN LOSS OF SENSIBILITY AND ATAXIA.

We have seen that it is possible to prove the loss of normal sensibility to passive movements in the joints even in cases in which the

ataxia is only very slight; we shall now have to answer the question *whether in tabes dorsalis one may find loss of sensibility without ataxia.* If the cases are examined according to the principles that have been developed in a previous chapter, the number of cases in which one finds loss of sensation in the joints coupled with absolutely normal coordination will be reduced to a minimum. These few cases are in the pre-ataxic stage, and are explained by the general economy of the body; the loss of sensibility is only a slight one, and can only be ascertained by the most careful examination; it must, of course, have reached a certain intensity before it can visibly influence coordination. We know that slight diminution of sensibility to passive movements may be compensated by increased innervation of the muscles in the neighbourhood. It is also easy to understand that in those joints which are of only a very slight or of no importance for the coordination of movements the sensibility may undergo diminution without the coordination of the limb being in the least affected thereby. Such joints are the joints of the toes; in them the first changes of sensation take place, but the movements of the toes are not in any way visibly impaired by them. The excursions of their movements are very short, the movements take place round *one* axis, so that a *moderate* degree of loss of sensation may exist without any visible influence on coordination. The same degrees of loss of sensation which passes unnoticed when confined to toes and ankles would, of course, produce most lamentable incoordination in the wrist and finger-joints. The compensation is produced by increased contraction of the muscles surrounding the joint, for in a joint sensibility to active contractions suffers much later than sensibility to passive contractions. At first this increase of innervation will be scarcely noticeable; later it makes itself felt in a certain stiffness of the joint. This stiffness should already be looked upon as a symptom of incoordination, however little ataxic it may appear to the observer. Little by little all manner of manœuvres are made use of, such as rubbing the toes on the ground and so on, in order to make up for the loss of sensibility. The eye plays a most important part in this respect, and, conversely, the elimination of the control of the movements by the eye is one of the first means of detecting even the slightest incoordination. There has never yet been seen a case of tabes with appreciable loss of sensation in the joints and muscles in which incoordination had not also been observed. Very rarely can organic diseases of a non-tabetic nature be utilized for the elucidation of this question, because those cases only are of value here which exhibit intact muscular strength coupled

with partial or total loss of articular and muscular sensibility. In a case of Brown-Séquard's, unilateral transverse lesion of the spinal cord produced by a stab with a knife, reduced cutaneous sensibility was found in the one leg and diminution of orientation in the other, without paresis, but slight ataxia, which was increased when the patient shut his eyes.

For the purpose of establishing the fact that the loss of sensibility is directly proportionate to the loss of coordination, it is necessary to examine the joints one by one with the patient either sitting or lying down. The *greater the loss of sensibility in a joint, the greater will be the ataxia in that joint;* this can be best proved by comparing identical joints in a number of patients; but this proportionality can be found in one and the same patient even, for as a rule the symmetrical joints are not affected to the same degree. It is not at all difficult to shew that the leg or arm the sensibility of which is more affected is also more ataxic, both as to its function as a whole as well as to that of every single joint.

With regard to the faculty of locomotion, it is necessary to remember that locomotion is a most complicated function of the human body, and that its impairment, although it is caused by tabes, is not entirely due to the loss of coordinated movements; there is, for instance, muscular hypotonia, flaccidity and relaxation of the capsules of the joints, which considerably modify and diminish the ability of walking. The flail-like condition of the capsules is the result of the weight of the limbs; if the ankle-joints are affected, the patients are in constant danger of falling through the foot turning over, and if the knee and hip joints are attacked the stability of the body is upset altogether. In walking and standing the sensibility of the skin of the sole of the foot is of great importance. If there is much loss of sensibility, standing becomes almost a thing of impossibility. Very instructive are those cases in which the greatest loss of sensibility, and consequently of coordination, is confined to the hip-joints and the lower end of the vertebral column. The patients shew genuine ataxia of the trunk, which sways to and fro in severe cases, even in sitting; when the eyes are shut these swaying movements become so excessive that the patient threatens to fall from the chair. This type of ataxia is often combined with hypotonia of the muscles of the spinal column. When the ataxia of the trunk becomes severe, the patients are obliged to keep to the bed. It is this class of case which at the first glance seems to furnish an argument against the theory that the incoordination is the result of the loss of sensibility; the careful observer, how-

ever, will not allow himself to be misled by the apparent freedom of the legs from ataxia, and will look for the cause of the ataxia of the trunk in the hip-joints and the joints of the lumbar vertebræ.

THEORY OF TABETIC ATAXIA.

Our arguments, so far, have shewn that the "centre" theory of ataxia is absolutely untenable, and that those who pin their faith upon the "sensory" theory have had to leave a number of objections unanswered. Such objections were the disproportion between loss of sensation and loss of locomotion, the existence of loss of sensation without ataxia, and so on. In reality, the supporters of the theory asserting loss of sensation as the cause of ataxia used only *one* clinical argument, namely, that loss of sensation was present in every case of ataxia. That this axiom did not meet with universal acceptance is largely due to the fact that the examinations of the patients had not been conducted with the necessary precision. When Goldscheider, for instance, says that hypotonia has nothing to do with ataxia, he is absolutely right, and we entirely agree with him so far; but he entirely neglects that the locomotion of the tabetic and the exaggerated excursions of the limbs are dependent not only on the ataxia, but also on the hypotonic condition of the muscles and joints.

An analysis of the laws that govern the coordination of the movements shewed that the continued and uninterrupted intervention of sensory impressions which come from objects around us, as well as from moving parts of our body, take an indispensable part in the production of coordination. These sensory impressions are not only necessary for the acquisition of new movements, but are absolutely necessary for the performance of movements that have already been acquired. Without them suitable—that is, coordinated—movements are impossible. We have further seen that our relations to the external world are chiefly based on the sensibility of our skin, and those to the limbs of our body depend on the sensibility of joints and muscles. It follows, therefore, of necessity that impairment or loss of the sensibility of the skin, joints, and muscles causes motor disturbances. Erb, who for well-known reasons could not accept the theory that loss of sensation was the cause of ataxia, nevertheless considered it plausible that the loss of sensation has a great influence on the movements of the joints, whether it be at their commencement or for the purpose of ascertaining the position of the limbs; but he

believes that the coordination proper, or the so-called "narrower" coordination, is an exclusively central function. The dualism thus created may be easily overcome if we remember that we perceive the limbs of our body as objects of the external world, and that their various conditions are transmitted to the central nervous system by means of sensory impressions in the same way as if they belonged to the world outside. This applies to any given phase in the course of a movement in the same manner as to the passage from a state of rest to a state of motion. The necessary accuracy and graduation of the sensory impressions for every single phase of a coordinate movement could impossibly be furnished by the sensory qualities of the skin. Different conditions prevail as regards the muscular and articular systems. Here we can prove experimentally the existence of an extraordinary fineness of sensation to passive, and a still finer sensation to active, movements, which makes it possible that each phase of the movement is brought to the knowledge of the sensitive organ.

This theory enables us to explain, *from one principle*, all the anomalies of the voluntary movements which we observe in the non-paralyzed and not weakened muscles of the tabetic. During the so-called pre-ataxic stage the stiff gait and the abnormal tension of the muscles during movements is due not only to the hypotonia that is developing, but also to a loss of articular sensibility which is compensated by an exaggerated contraction of the muscles which are attacked much later, so that by this means sensation of the position of the limbs is produced sufficiently. Whenever a tabetic shews a certain stiffness of the legs in walking as the only symptom of locomotor disturbance, one is always certain to find a change in the sensibility of the joints and intactness of the muscular sensibility. In the early stage of ataxia the combination of exaggerated muscular contractions and superintendence of the limbs by the eyes is always sufficient to compensate the loss of sensibility. When the eyes are shut the ataxia becomes prominent. The exaggerated excursions of the limbs and the disproportionately large amount of muscular work which characterize tabetic ataxia prove that one is at least partly justified in believing ataxia to be a reaction produced by the loss of sensibility, for it is not absolutely necessary for ataxia to be accompanied by excess of muscular work; nay, incoordination may be due also to a diminution of the normal excursions and power of the muscles, while the diminution of sensibility of necessity requires increased work and excessive excursions on the part of the muscles.

The theory which bases tabetic ataxia on the loss of sensation helps somewhat to explain the so-called paralytic stage of locomotor ataxia. We cannot agree with those who believe that the paralytic stage is caused by a complication of tabes with a lesion of the motor portion of the spinal cord or of peripheral nerves, because we have no post-mortem evidence, and, secondly, because in some cases it is possible to convert the paralysis into simple ataxia. We are rather inclined to seek the cause of the paralytic stage of tabes in the anæsthesia of the skin, joints and muscles, which is a constant symptom in this stage of the disease.

The theory deserves careful attention, that the performance of a voluntary movement by a certain group of muscles demands not only central innervation and integrity of the motor tract, but also the existence of a certain amount of sensibility of the muscle itself. According to it, anæsthetic muscles cannot be made to contract voluntarily; applied to our theory of ataxia, it means that partial loss of sensibility produces ataxia, total loss paralysis. From a functional point of view, it is indeed more probable that the possibility of prompt innervation of a certain group of muscles depends on the reception of centripetal stimuli from this group, rather than that the central nervous system should at any given moment and quite independently have the whole scale of muscles at its command. Experiments made by Sherington, Korniloff and Hering, who severed the posterior roots so that total anæsthesia of the limbs was the result, shewed that the anæsthetic limbs were also paralyzed.

Of great practical and theoretical interest is the observation which is pretty frequently made in tabetic patients, namely, that they forget the proper sequence of certain movements. The first movement, for instance, which a healthy person would make who wanted to get up from a chair would be to draw back his legs. The ataxic who does not remember this most necessary initial movement often makes hard but fruitless efforts to get up from the chair, until he is reminded that he ought first to draw back his legs. Another similar symptom is that tabetics often make great efforts to bring one leg before the other, but they do not succeed, simply because they forget to shift the balance over to the other leg, a movement which healthy people perform automatically. This anomaly plays a most important part in the locomotor disturbances of tabes, and is no doubt connected with the loss of sensibility. If we observe these patients at the performance of certain movements which healthy people make automatically, such as going up or down stairs, we find that if they are at

all able to execute the movements, they behave all alike in doing so. Their movements shew only one constituent of "ataxia," namely, increased muscular tension; they appear to be identical with the "cautious" movements of healthy persons walking on unsafe ground or in darkness. These "cautious" movements of the tabetic must be classified as incoordinate movements, for they appear quite unsuitable if compared with the movements of a healthy subject who has the same task to perform. But this analogy with the cautious movement of a healthy subject on dangerous ground lets the movements of the tabetic appear as a proper reaction to certain motor disturbances; they suit his purpose because they enable him, in spite of his loss of sensibility, which alters his relation to the outer world and his own limbs, to walk up or down stairs. We can similarly regard every ataxic movement in tabes as a reaction to the loss of cutaneous, muscular and articular sensation. By increasing the force of the contractions of his muscles and the excursions and celerity of his articular movements the patient uses the means which he finds at his disposition for the partial replacement of the loss of sensibility which interferes so much with his locomotion.

The influence of the optic sense on the incoordination is easy to explain. The intimate relations between an optic impression and the corresponding innervation are a matter of daily experience with us. We know, further, also from experience, that the control of our movements by the eye becomes more or less superfluous as regards the promptness of such movements, if we receive other "local" reports from the skin, muscles, joints, etc., which inform our central nervous system as to the relation of ourselves and of our limbs respectively to the objects of the outer world. If, however, sensation has been partially or absolutely lost, the control of the movements by the eye becomes absolutely necessary, especially as the limbs behave towards the impulse of the will as if they did not belong to the same body. There is no difference in principle between the manner in which the hand of a healthy person seeks an object in a dark room and that in which the leg of a tabetic tries to execute its movements.

Every ataxic movement becomes still more ataxic as soon as its control by the eye ceases. This is an axiom to which there is no exception, and which is entirely due to loss of sensibility. The so-called Rhomberg's sign is only one instance of this general rule. Standing is a complicated feat of coordination which must become unsafe if the sensibility of the various parts of the body becomes impaired, and the deficiency thus created is not made up by ocular

control. When Rhomberg's sign is present, the sensibility of the motor apparatus or of the skin of the soles of the feet will always be found impaired. The intensity of the symptom depends entirely on the amount of the deficiency of sensation. A few cases have been reported in which blind tabetics shewed Rhomberg's sign whenever they shut their eyes. We have never met with such a case, and are unable to give an explanation, unless it be that these patients still had some perception of light. We shall see later that the good results obtained by the treatment of tabes by means of systematic exercises have given new support to the theory which holds that ataxia is caused by loss of sensation. These good results cannot be explained from any other point of view.

II. SPECIAL PART.

The most important characteristic of the nervous substance is its ability of being exercised—that is, of reproducing in a peculiar manner impressions, or, more generally speaking, states of innervation which it had already undergone a great many times. The ability of preserving received impressions or former conditions, be they mental associative functions or motor stimuli, is the necessary presumption of normal life. Of course, we do not know what modifications of its structure the nervous matter has to undergo when it has to learn a new language, or to associate new movements, such as playing the piano, for instance; but we know the premises under which such a modification must take place. Three things are necessary to enable us to learn something new: its apperception must be precise, the attention of the mind must be concentrated upon it, and the mental impression it produces must be frequently repeated. Any action which has been acquired or developed under the above-mentioned conditions becomes so thoroughly combined with the voluntary impulse that it is reproduced without that peculiar sensation of exertion which is attached to every action that is unfamiliar to us; so that it appears as if the will-power of which the concomitant feeling of exertion is our only index, did not intervene at all—a supposition which is psychologically impossible. A movement which has been "learnt" possesses besides that continually decreasing feeling of exertion this peculiarity that it can be repeated quickly and with precision—that is, without visible intervals between its various phases.

THE PRACTICE OF MOVEMENTS.

We have seen that in order to "learn" a movement it is required that the motor stimulus be repeated, and that the attention of the mind be directed to it. At first the movement is accompanied by a more or less prominent sensation of muscular fatigue, which

decreases as the movement becomes more familiar. Further, one notices at the beginning of the practice movements which are absolutely useless, because they are quite outside the purpose for which the movements are intended; these useless movements disappear after a time. This sensation of fatigue and those useless movements shew that at the beginning of the practice of new movements the work of the muscles is exaggerated, that they contract with unnecessary force, and call into play muscles which not only have nothing to do with the intended movement, but even impede and distort it. Hence we must conclude that under the influence of that complicated function which we call muscular practice a selection takes place of the muscles and amplitudes of contraction that are most suited for the purpose. Under the influence of practice the parts of those muscles which form an anatomical unit become more independent. Thus, we know that in learning to play the piano the various muscles which form the common extensor muscle of the fingers become independent of one another, so that each individual finger may be extended promptly and without exertion, and that the wrist-joint learns to move alone and independently of other joints; in singing the muscles of the larynx do not only become independent of the respiratory movements, but also of the muscles of the pharynx. The result of the practice of movements, therefore, is that various component parts of the groups of muscles which form an anatomical and physiological entity become so emancipated from each other that each individual muscle becomes perfectly independent. The exertion necessary for the production of the movement, and the duration of it, is, therefore, nothing else but the visible expression of the battle between the tendency of physiologically allied muscles to collaborate whenever one of them is called into play, and their emancipation from this collaboration in the interest of an intended specific movement. The marvellous performances of jugglers and acrobats, which are the result of an exceedingly subtle combination of the most varied muscles, shew to what perfection this dissociation of originally combined groups of muscles can be brought.

When a new combination of muscular contractions is being acquired, the sensory impressions which are received from the joints and muscles of our extremities and from the objects with which they come into contact are rearranged or eliminated, as the case may be. In the case of muscular contractions requiring the perception of minute tactile impressions, as in many fine handicrafts, or in estimating the resistance of the keys of the piano or of the strings of

the violin, the acquisition of such fine muscular movements is made possible by that characteristic quality of the nervous system to accumulate the impressions produced by the frequent repetition of minute stimuli until their collective intensity equals that of a stronger but less frequent stimulus. It would be wrong to suppose that those persons who, like the blind, when reading have naturally to rely on the differentiation of minute tactile impressions, really acquire an objectively greater acuity of tactile perception; in reality, the precision with which they perform the required movements is the result of long-continued practice by which the central nervous system has learnt to be satisfied with an oft-repeated minimum of tactile impressions.

EXERCISE AS A MEANS OF COMPENSATING LOSS OF CO-ORDINATION.

The treatment of tabetic ataxia is based upon the education of the central nervous system by means of repeated exercises, whereby it is enabled to receive sufficiently distant stimuli from the limbs as to their position and so on, although the available quantity of sensation is rather small. It is necessary, of course, that the movements be attempted and carried out *repeatedly and with great attention*. Repetition enables the central nervous system to differentiate stimuli of minute intensity; its sensibility becomes so great that often repeated slight stimuli act on it with the same force as rarer but much stronger impressions. Theoretically, the transformation of an ataxic movement into a normal movement takes place in tabetic subjects according to the same laws as the acquisition in healthy persons of a complicated movement which acquires the differentiation of tactile impressions of minute strength. A certain minimum of sensation, however, is absolutely indispensable; complete anæsthesia precludes the application of the treatment by exercise, but, fortunately, such cases are very rarely, if at all, met with. The greater the loss of sensation, the longer and the more difficult will be the treatment, and the more uncertain the result. Soon after the publication of the author's method several writers declared that it was only applicable to cases where the sensibility of the muscles and joints was still intact; but this view cannot be accepted for two reasons: first, because tabetic ataxia is *always* combined with more or less marked loss of sensibility of the joints and muscles, and, secondly, because in many cases observed by the author and Hirschberg, *splendid results had been*

obtained by the exercise treatment, although there was an extreme degree of loss of muscular and articular sensibility.

Actual improvement of the sensibility of the skin through exercise treatment was first described by Bechterew and Ostankof; such cases are rare, however. One constantly meets with a marked improvement of orientation, so that the patients declare spontaneously that they are now able, without looking, to define the position which their lower limbs occupy in bed. Pressure is also better felt, so that in standing, *e.g.*, the patients feel, or feel more distinctly, the pressure which the hard ground exercises on their soles. Attempts to increase or accelerate the improvement of co-ordination by means of aural or ocular impressions which the patient receives during his exercises have had no practical result.

The principal thing to do in this treatment is to find out for each limb the kind of exercise which is most apt to compensate the loss of sensation. As a rule, it is essential that the sensibility should not have been reduced below a certain minimum; but in some *special cases an almost complete cure has been effected, although at the beginning of the exercises the residue of sensibility was almost nil.* Such patients are obliged to follow the movements of their body and their limbs with the greatest attention; they fall down immediately they shut their eyes. One of the most interesting examples of this class of case was furnished by a patient who began his treatment with an ataxia so severe that he could not move out of his arm-chair. He was a man of most extraordinary will-power, who at once entered upon the treatment with the greatest determination, and who followed each movement of his limbs or body with the closest attention. After eight months' treatment he went home *perfectly cured.* He had even learnt to walk down the stairs backwards, and without the help of a stick. But he could not dispense with the control of the eyes; he fell down as soon as he tried to shut them. If the loss of sensation has not been so great as to reduce the residue of sensibility below a certain minimum, one usually succeeds in teaching the patient to stand or walk with his eyes closed; but the movements will always be more undecided than when they are made under the control of the eyes. We have no means of defining the minimum quantity of sensation which is necessary for producing a good result; but it is sufficient if the patient has a vague sensation of the active or passive movements which are performed by his limbs. If the patient has a strong will and is able to give close and continued attention to the task he has to perform—a faculty which is much rarer than is commonly supposed—the result

of the treatment will be excellent, with that unavoidable exception that the patient must keep his eye on his movements, as it were. Such patients are able, when lying on the back, to carry out movements with perfect coordination, and when walking they walk perfectly well with the single exception that there is more or less hypotonia and curving backwards of the knees, or outward rotation of the thighs.

All healthy persons move their limbs with a certain amount of steadiness and precision. Tabetics who have undergone the exercise treatment and have lost their ataxia shew no obvious differences from the normal state, as long as their attention is not called away from the task they are just performing; but they shew a great deal of hesitation and indecision when their attention is directed to something else. In such cases all depends on their determination and endurance; they must continue carefully and persistently to superintend their own movements for many months after their discharge, lest they will quickly return to their former ataxia; for this reason it is better for patients whose initiative and will-power is weak to remain in the sanatorium for some months after the treatment proper has been concluded, until they have completely mastered their daily task and have acquired the habit of continuous and painstaking supervision of every detail of their movements. If the exercises are practised daily with the same attention, the movements continue to gain precision.

Before we proceed to describe in detail the various exercises, we must discuss the mechanism of the movements of the body, for the correct diagnosis of the various tabetic anomalies of movement and the prognosis depend on our knowledge of the movements of the human body and the laws regulating them

THE MECHANISM OF THE MOVEMENTS OF THE HUMAN BODY.

In standing the body rests on two cylindrical supports; the trunk, head and upper limbs are kept in the equilibrium by reason of their position above the lower limbs, which in turn are kept in the equilibrium by the evenly distributed weight of the body. That this is so is proved by our ability of standing on one leg only. The distribution of the weight of the body so that it keeps its balance above the lower limbs is produced by the muscles, which by their contraction not only shift their own centre of gravity, but also rearrange the position of the various parts of the skeleton to one another. The axes round which this redistribution of the weight of the body

takes place lie in the joints. The feet and the spinal column possess many and variously situated joints of small amplitude, which are arranged in groups and joined together by numerous fibrous bands. This multitude of joints insures precise and quick adaptation of the centre of gravitation ; it alone produces that ability of safe and quick equilibration of the body which makes walking possible. The antagonism of the muscles, ligaments and fasciæ of the joints and muscles acts as a moderating and correcting influence. The erect habit of the human body depends entirely on active muscular contractions; it is impossible permanently to poise a dead body on its legs.

Without this elaborate system of segmentation, none of the multifarious movements of the body could be executed. This advantage, however, becomes at once a disadvantage if the prompt co-operation of the muscles is disturbed in consequence of some morbid change. Then the great mobility of the body has a disastrous effect on locomotion, for the greater the number of the parts, the less stable is the equilibrium. The muscles make a certain number of joints immovable for a time, while they are not immediately wanted. This automatic reduction of the number of supple joints produces the stiffness of the back and gait which characterizes tabetic patients, even when they do not suffer from muscular spasms. This is chiefly the case in the beginning of the disease, when the quality of the action of the muscles is as yet intact, but the precision of the movements begins to be impaired. We have called this symptom the pseudo-spastic gait of the tabetic. It explains why at the early stage of the disease the patient complains of becoming easily tired.

It is necessary now to discuss more fully the action and influence of the mobile segments on the various movements of the body.

1. **The Foot.**—In standing erect with the feet parallel and in apposition, the line of gravity of the body descends somewhat in front of the heels. The greatest weight, therefore, rests on the heels, where the epidermis, even in the newly born, is thicker than in any other part of the body. The length of the foot makes it possible to transfer the centre of gravity to more anterior parts of the foot, as is done in bending forward. The portion of the foot between the heel and the ball of the great toe is concave, and does not rest on the floor; when the body is bent forward, the weight of the body rests on the balls of the great toes. In extreme degrees of anteflexion of the trunk, the heel is raised from the ground, the foot rests on the toes alone, and is supported in this position chiefly by the great toes.

Compared with the solid bony support which the heel affords, the toes can give but uncertain hold. In order to bring the line of gravity as close to the heels as possible, while the body is being bent forward to an extreme degree, the thighs and legs are curved backwards as much as possible; but from anatomical reasons this compensatory curving backwards can take place only within very moderate limits, and it is entirely absent when the body and lower limbs are being held stiff and extended, while the anteflexion takes place in the ankle-joints. In this case the centre of gravity is at once shifted forward into the neighbourhood of the ball of the foot, and the heels are *passively* lifted off the ground. The ankle-joint itself would allow of a very wide range of forward movement without necessitating the heels to be raised, but the law of gravitation does not permit the transference of the line of gravity beyond the supporting base. Bending backwards is possible only within very narrow limits, and is impossible when the body and lower limbs are being held stiff and extended, as in this case the centre of gravity would at once fall beyond the supporting base. To enable any bending backwards of the body, the knees and hip-joints must perform compensatory movements by which the centre of gravity is again brought within the area of the heels. The spinal column itself allows of very little extension, and a special arrangement of ligaments makes it next to impossible in erect position to bend the body backwards by trying to overextend the hip-joint.

Fig. 32.—Normal. Body bent Forward: Thighs and Legs behind the Line of Gravity.

2. **The Knee-joint.**—Normally, when a man stands erect, the knee-joint is slightly hyperextended; when his attitude is more careless,

the knee is slightly flexed (Fig. 22B). This attitude is partly due to the extension of the flexor muscles, which are inserted into the tendo Achillis, and which, in consequence of their tone, are shorter than the added lengths of the bones which they cover. The more this group of muscles is extended, the greater is their tendency to produce flexion of the knee-joint. This happens whenever the ankle-joint is dorso-flexed, as is the case in walking. The flexion of the knee-joint is of great importance to the organism, as it helps to diminish and modify the series of upward pushes which the body receives in walking or running; when the weight of the trunk is transferred from one leg to the other, the bent knee, acting like a spring, prevents any violent contact between the articular surfaces, and thus produces that elasticity which characterizes the natural gait. Without it, walking for any length of time would be absolutely unendurable. In jumping the *knees are naturally kept bent when the ground is touched.* People who have to stand for many hours or have to carry heavy loads always keep their knees more or less bent; the angle of flexion depends on the weight which the legs have to carry. This flexion of the knee-joint, which in a way must be regarded as a protective measure, is not *a function of the will, but of anatomical conditions.* Thus, the excursions of joints are not solely determined by the shape of the articular surfaces of the bones and the length of the capsules, but also, and that to a very large degree, by the tone of the muscles. Flexion of the knee-joint is nearly always associated with flexion of the hip-joint. We have shewn in the chapter on hypotonia to what large extent the flexion of the hip-joint depends on the bending of the knee.

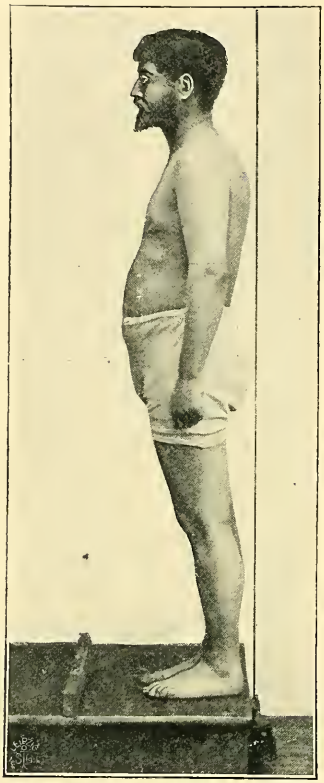

Fig. 33.—Normal. Relation of the Perpendicular to the Body in Erect Posture.

3. **The Hip-joint.**—Fig. 3 shews that normally the thigh can be freely flexed upon the pelvis only when the knee-joint is being

flexed at the same time. When standing erect the lower limb can be raised beyond a certain angle only when the knee is being bent as well; otherwise the movement in the hip-joint is very limited (Fig. 34). The importance of the flexion of these two joints together for locomotion is obvious. The hip-joint possesses a powerful ligamentous apparatus which fixes it in position, and it is further limited in the performance of excessive movements by the massive muscles which surround it; the lateral movements of the joint are limited by the tone of the adductors; from anatomical reasons the backward movement of the hip-joint is very limited indeed, and can only take place when combined with plantar flexion of the foot.

Fig. 34.—Normal. Maximum Flexion of Hip-joint with the Knee extended.

4. **Standing on One Leg.**—This movement, which is of supreme importance for safe locomotion, depends on the ability of transferring for a short time the whole weight of the body on to one leg, and on the mobility of the foot in the ankle and ball joints, whereby the centre of gravity can be shifted quickly. In standing on one leg the body leans over to the side of the supporting limb, and the foot makes slight oscillating movements. At each step during walking the body rests for a moment on one leg, but it immediately afterwards begins to let itself fall over, and on to the other leg. Healthy subjects have no difficulty in supporting themselves on one leg, and in keeping the thigh, leg and foot of the other limb flexed at right angles (Fig. 35). But the slightest uncertainty as to the firmness of the base lets these angles become obtuse, especially with regard to the hip-joint. Such persons flex the hip-joint very little, but bend the knee-joint the more (Fig. 36). The

result is an abnormal but very constant attitude, which has a considerable diagnostic value, because it is a very early symptom in tabes dorsalis, and appears long before the loss of coordination becomes obvious. We have seen that the maintenance of the equilibrium in the various positions which the body occupies in the course of the routine work of the day depends chiefly on the accuracy with which the trunk adapts itself to the various changes of its position. If the lower limb is lifted up, the body must be bent backwards to compensate the forward movement of the centre of gravitation; if the leg only be bent upon the thigh, the trunk is slightly bent forward (Fig. 37). If, then, the thigh be slightly bent, the body answers this flexion by a backward moving (Fig. 38). A comparison of Figs. 37

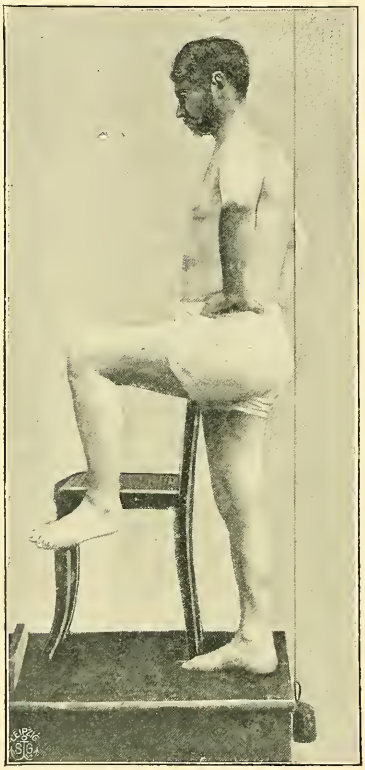

Fig. 35.—Normal. Standing on One Leg.

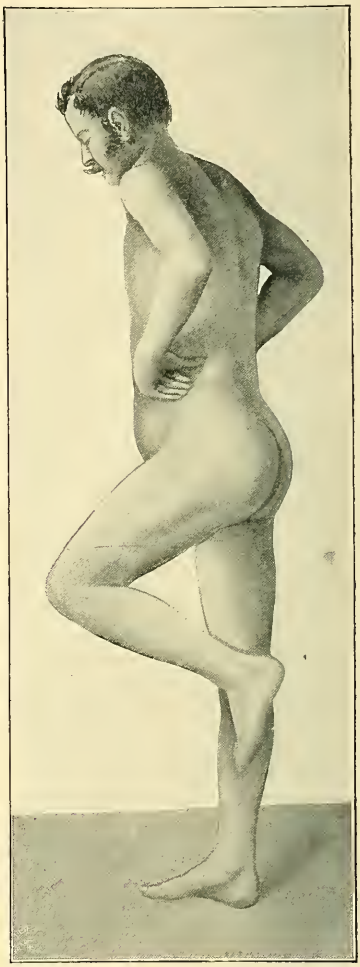

Fig. 36.—Beginning Tabes Dorsalis. Standing on One Leg.

and 38 shews that the pelvis remained relatively immovable, and that the hip-joints form the axle round which the compensatory movements of the trunk take place. We can now understand why persons who feel not safe on their legs in consequence of partial loss of sensation adopt an attitude like that in Fig. 36, when they are told to stand on one leg: it is because in doing so they have to make only

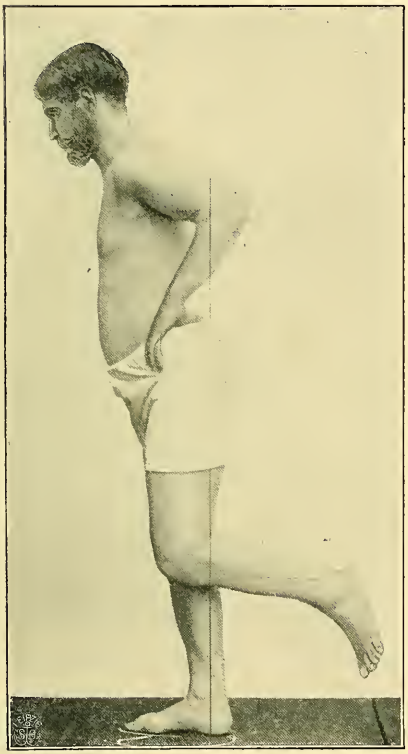

Fig. 37.—Normal. Leg bent upon the Thigh, which is not moved; Compensatory Bending Forward of the Body.

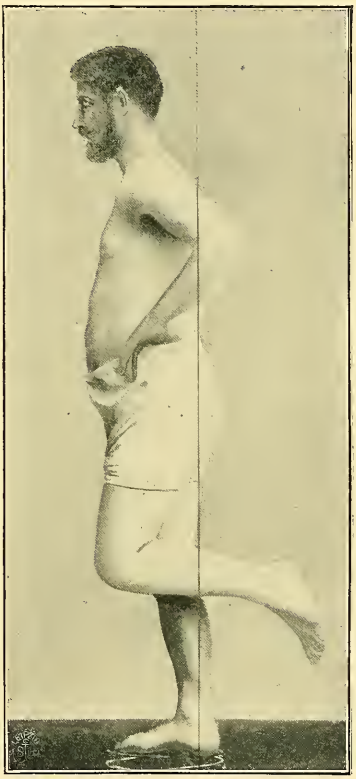

Fig. 38.—Normal. Thigh slightly raised, Knee bent. Body moves back into the Perpendicular.

the slightest change in the usual position of their pelvis. It is interesting *to find already at such an early stage of locomotor ataxia doubtless evidence of that tendency of fixing the trunk which becomes more and more prominent as the disease progresses.*

5. **Bending the Knees.**—When tabetic persons are asked to bend their knees and at the same time to keep their body perfectly upright, in the same way as is done at the gymnasium, they do not lift their

heels off the ground and bend their knees, keeping the thighs slightly abducted and their body erect, but the whole length of their feet rests on the ground, while the body is bent forward and the pelvis pushed back until the balance is established. The angle between the dorsum of the foot and the leg is capable of very little variation. The reason for this peculiar manœuvre of tabetic subjects is obvious: The whole foot gives the patients greater security than the toes alone can give.

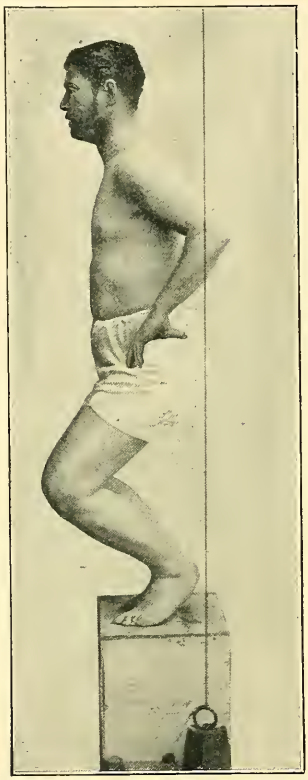

FIG. 39.—NORMAL. BENDING THE KNEES WHILE HOLDING THE BODY ERECT.

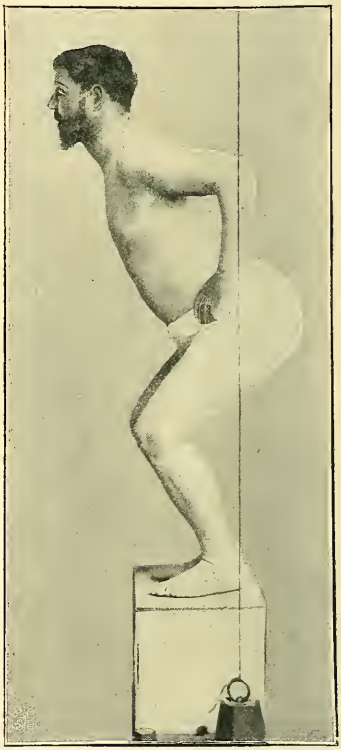

FIG. 40.—MAXIMUM FLEXION OF LEG IN THE ANKLE-JOINT.

This is another early pathognomonic sign of great value. Fig. 40 illustrates the maximum flexion which is possible between foot and leg. If for some reason the knee is pushed further forward, the heel must of necessity be lifted off the ground, and the additional amount of flexion must be thrown upon the metatarso-phalangeal joints.

6. **Walking.**—In walking we put one foot on the ground some distance in front of the other, and pull the other foot after it; thus

the whole body is transported from its previous position to the new one. Walking, however, is a very complicated movement, and thus it becomes intelligible why patients who move their lower limbs relatively well when lying in bed find it so difficult to walk. The first phase is the transference of the whole weight of the body to one leg. This enables the other leg to be flexed in the hip-joint and to swing forward. The second phase is given by the forward movement of the trunk and pelvis, without which walking would be impossible. This movement transfers the weight of the body from the stationary leg to the leg that has just been put on the ground in front, and the leg behind can now be brought forward and put down by the side or in front of the first. This completes the first step. We have just described a short step (Fig. 41). When a longer step is made (Figs. 42 and 43), the centre of gravity is advanced from the heel of the stationary foot to the ball, the heel is lifted off the ground, and thereby the weight of pelvis and trunk is transferred to the other leg. *In making long steps the forward movement of the body is always attended by raising the heel of the stationary foot, whereas the heel need not be lifted up in making short steps.* Short steps are of a very limited importance in ordinary life; they are chiefly used when it is necessary to walk with caution on dangerous or unsafe ground, be it that it is difficult to maintain one's balance, or that sudden stopping may be required at any moment. Fig. 41 shews that in making steps shorter than the length of the foot the whole length of the sole rests on the ground, which not only increases the stability, but also enables the trunk to move forward parallel to its occipito-frontal axis, a circumstance which favours a sudden stoppage of the forward movement, if such be required. For ordinary purposes the long and moderately long step (Figs. 42 and 43) is used.

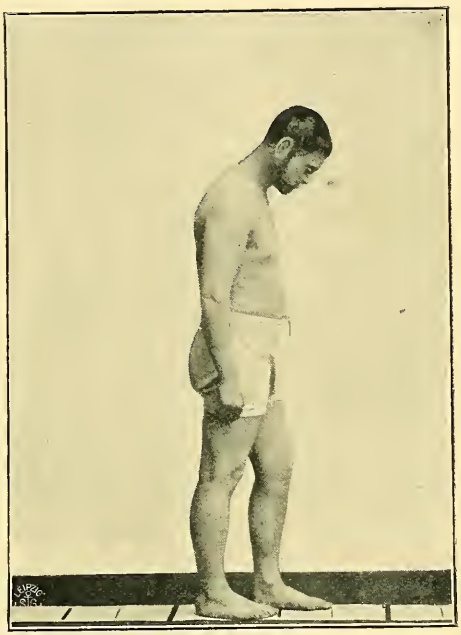

Fig. 41.—Normal. Making a Short Step.

In making a long step, while one lower limb is swinging forward, the heel of the foot of the other is lifted off the ground, and the foot rests on the ball of the toes when the first leg touches the ground with the heel and slightly extended toes. For a short

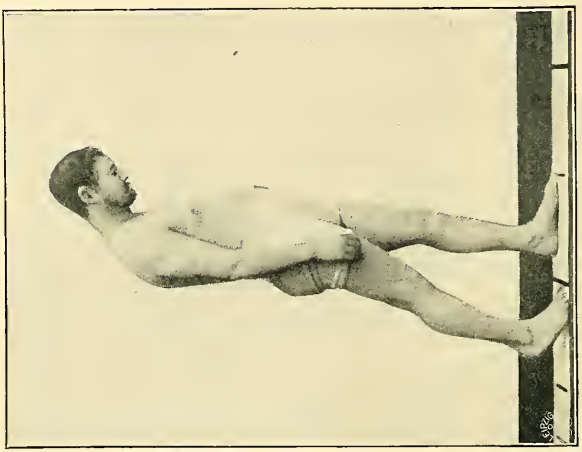

Fig. 43.—Normal. A Step of Medium Length.

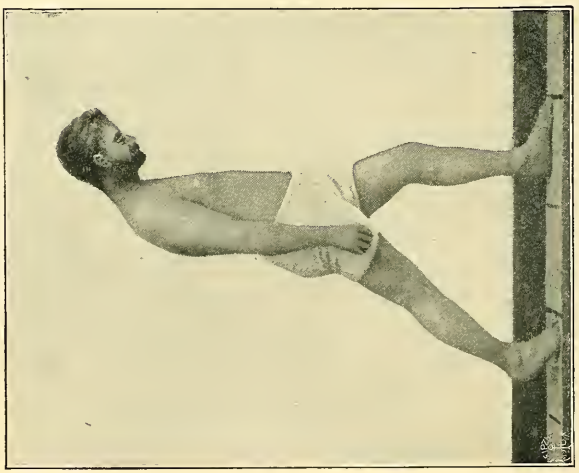

Fig. 42.—Normal. A Long Step.

time now both feet rest upon the ground. At the next moment the first leg rests on the ground with the whole length of its foot, whereas the foot of the other leg continues to disengage itself from the ground. As soon as it is completely lifted off, it swings forward in turn, and the whole series of movements begins anew.

The importance of the flexion of the knee becomes more obvious when we consider it together with the movements in walking. We have seen that at the commencement of a step the weight of the whole body rests for a moment on one leg only; this leaves the other free to move, but does not lift it off the ground. The easiest and safest way of doing this is, obviously, by flexion of the thigh in the hip-joint, accompanied by flexion of the knee; for it enables the leg to overcome obstacles in its path, and requires much less lateral movement of the pelvis and trunk than would be the case if the limb, with extended hip and knee joints, were to be lifted off the ground. A third advantage is that thigh, leg, and foot acquire at once that position which will be required of them throughout the walking movement—viz., flexion and dorsal flexion respectively, the only variable quantity being the magnitude of the angles. Lastly, the spring-like action of the extensors of the knee-joint prevents any violent contact between the articular surfaces at the moment when the weight of the body is transferred from one leg to the other.

We have already mentioned that in walking with extended knee the pelvis and trunk must describe a much more pronounced external movement than when the knee is bent. We know also that the thigh cannot be raised up high if the knee is kept extended (Fig. 34). The result, therefore, will be a very short step. Further, a glance at Fig. 34 will shew that the foot would touch the ground with the heel alone; this would render the position very unstable. If the foot were brought down in plantar flexion, so that the toes first touch the ground, the stability of the body would not be materially increased, while the strain on the muscles would soon cause great fatigue; the walking would result in a series of shocks to the whole body, as well as to each individual joint, which would have most serious consequences. It is not so much the movements of the lower limbs which make walking possible, but those of the trunk. If the trunk is immovable, it is impossible to walk. The trunk in walking moves forward, and from one side to the other; when a person has been standing at ease before, the first step is initiated by bending the body forward, whereby the centre of gravity is moved beyond and in front of the supporting base. As a consequence of this disturbance of the balance, the body falls forward until its fall is checked by the leg which had been put forward, and is pressed against the ground by the weight of the body that is now on it. When the walking movement is in progress, a great portion of the propelling force is furnished by the toes, which push the foot off the ground.

7. **The Mechanism of Walking in Tabetic Subjects.**—Besides loss of coordination and hypotonia of the muscles, tabetic subjects shew a very important anomaly, which accounts for their more or less complete inability of shifting the weight of the body when stepping out. The cause of this disturbance is the loss of sensation of the

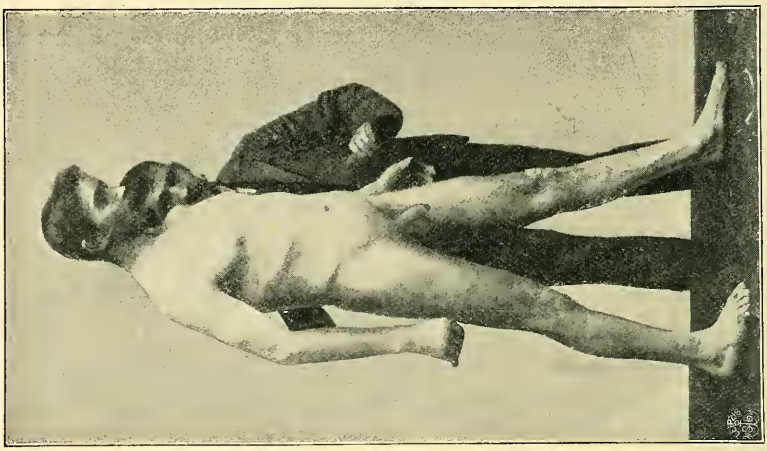

Fig. 45.—Long Step in Tabes Dorsalis.

Fig. 44.—Short Step in Tabes Dorsalis.

movements in the hip-joints and of the spinal column. In an advanced stage the trunk is held erect and stiff; the lower limbs are likewise stiff and extended; locomotion, always with support, takes place by means of short steps; the heels touch the ground first, the toes are hyperextended. This complex of symptoms is quite charac-

teristic of tabes with spinal and coxal anæsthesia; if one compares it with the exaggerated thrusting, stamping movements of the lower limbs in cases without such anæsthesia, the important part played by the pelvis and trunk in the tabetic motor disturbance becomes clear at once.

Tabetic subjects keep the weight of their body poised on the

Fig. 46.—Walking Sideways. Initial Position.

stationary leg; they almost pull the body after them when the step is completed, whereas healthy people use the weight of their body as their principal means of propulsion. Figs. 44 and 45, which illustrate short and long steps in tabes dorsalis, shew well this characteristic manner of walking. A comparison with Figs. 42 and 43

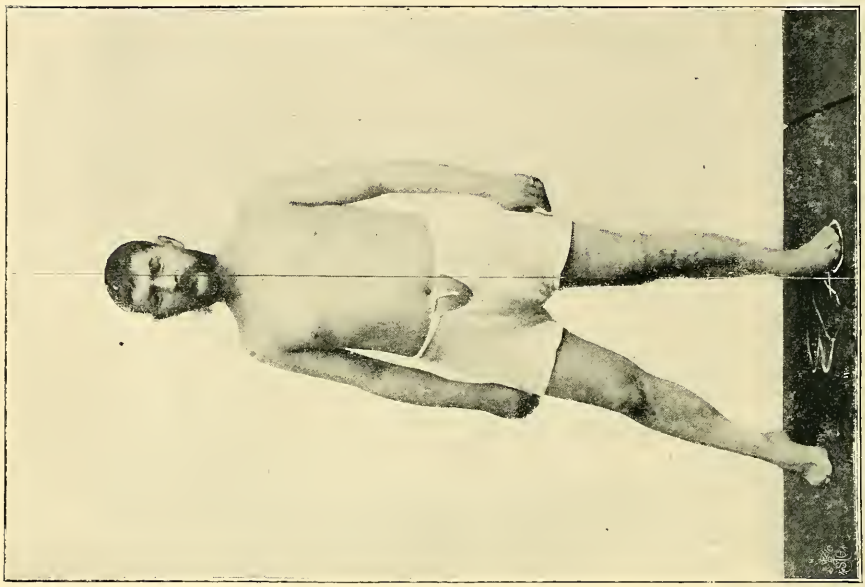

Fig. 48.—Walking Sideways to the Right. Second Phase: Body leaning towards the Right; Right Foot brought down.

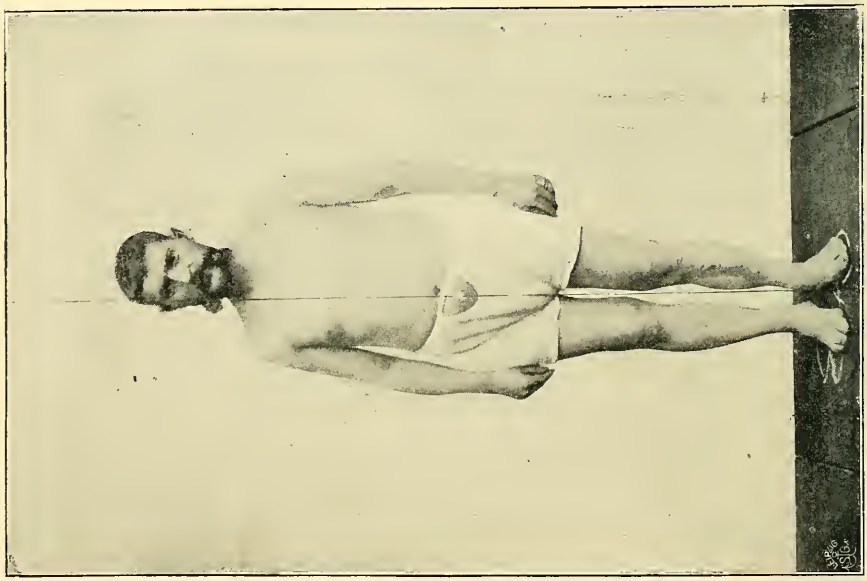

Fig. 47.—Walking Sideways to the Right. First Phase: Body rests on Left Leg.

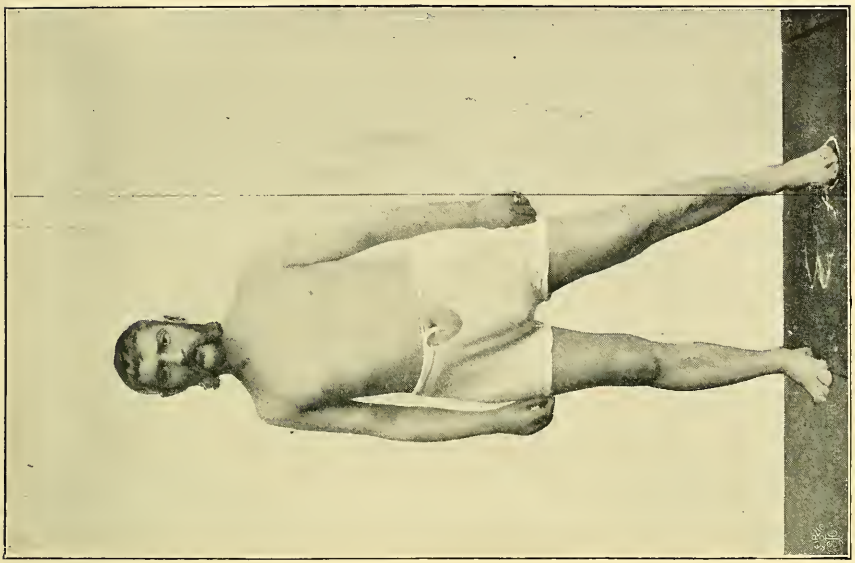

Fig. 50.—Walking Sideways to the Right. Fourth Phase: Body resting on Right Leg; Left Heel lifted off the Ground.

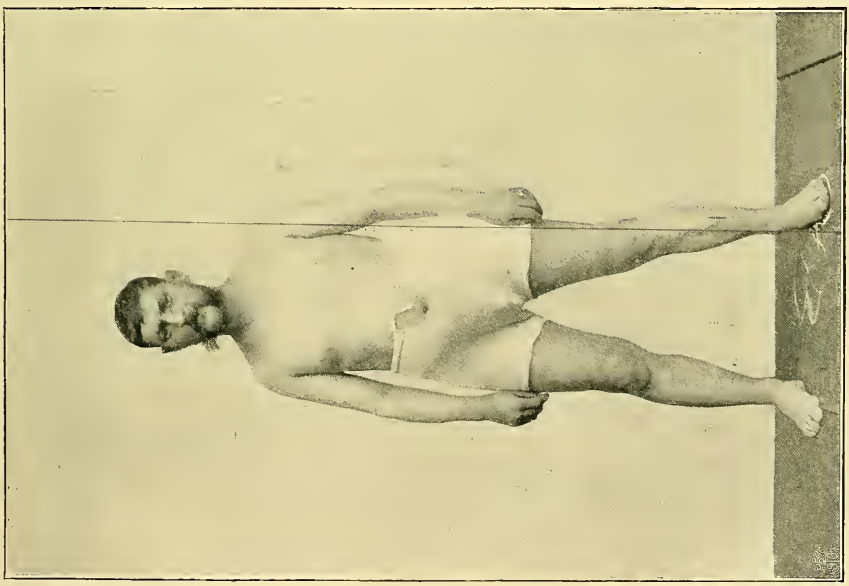

Fig. 49.—Walking Sideways to the Right. Third Phase: Weight of Body resting equally on both Legs.

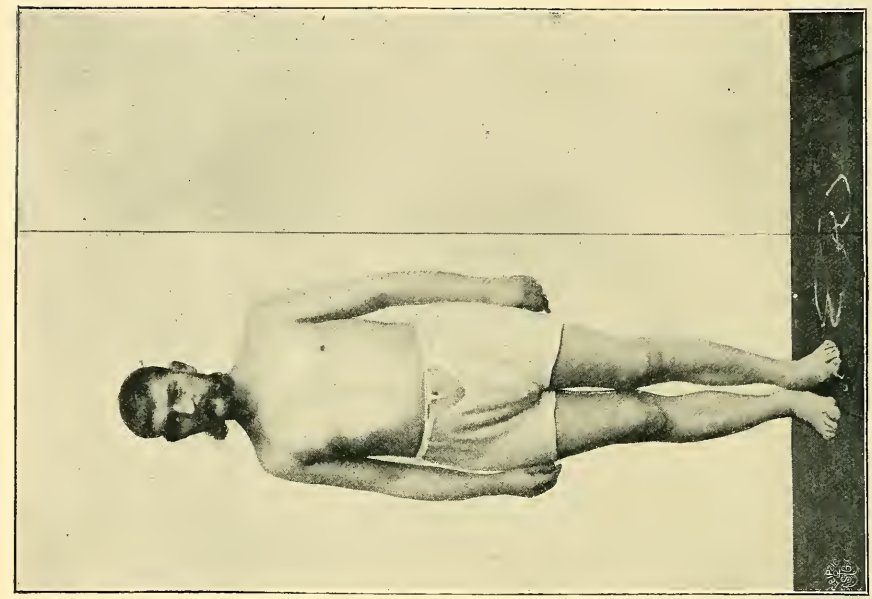

Fig. 52.—Walking Sideways. Sixth Phase: Resumption of Initial Position after the Step is completed.

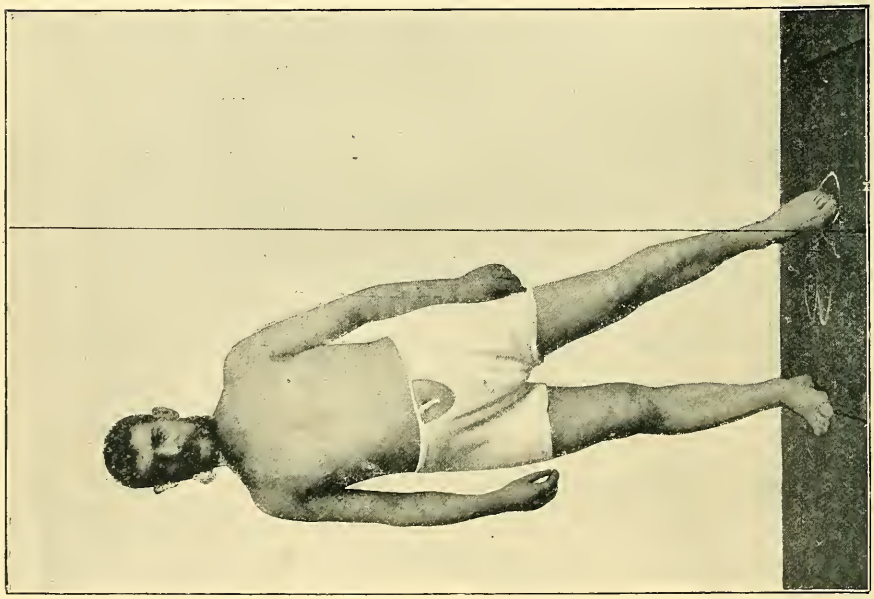

Fig. 51.—Walking Sideways. Fifth Phase: Body moving to the Extreme Right in order to liberate the Left Leg.

will shew the difference between the normal and the tabetic position of the trunk in walking.

8. **Walking Sideways.**—This is a much more simple movement

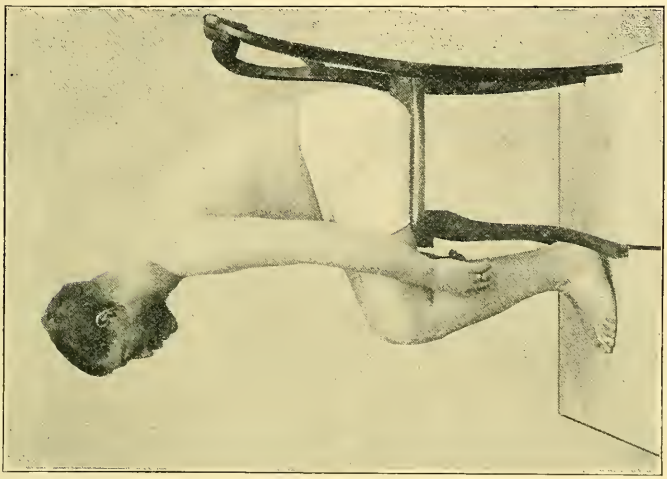

Fig. 54.—Getting up from a Chair. Second Phase: Drawing the Legs back.

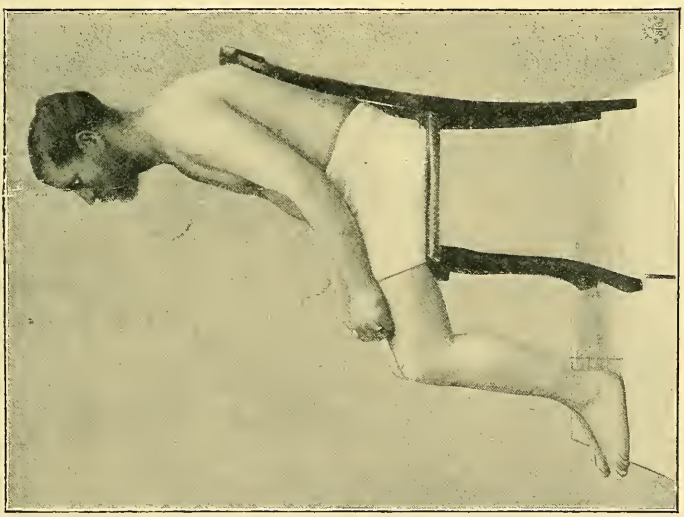

Fig. 53.—Getting up from a Chair. First Phase: Initial Position.

than walking backwards or forwards, because the legs and trunk move in the same plane perpendicular to the base. The body is not bent forward; tabetics find it therefore easier to walk sideways than forward. The simplicity of the movement makes it most suitable for

illustrating some of the more important principles of voluntary locomotion.

It is best to take as initial position the usual erect attitude in

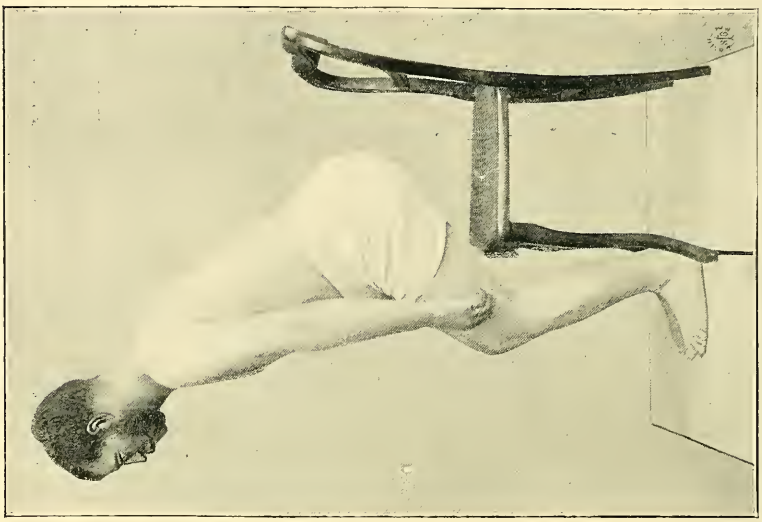

Fig. 56.—Getting up from a Chair. Fourth Phase; Extension of Trunk and Thighs.

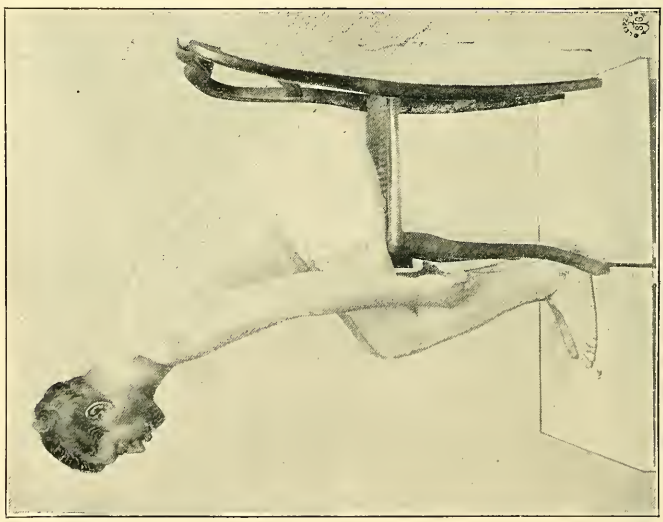

Fig. 55.—Getting up from a Chair. Third Phase; The Body is being bent forward,

which the weight of the body rests equally on both legs (Fig. 46). In moving to the right, the first phase (Fig. 47) consists in the transference of the weight of the body from both to the left leg, thus

liberating the right lower limb. Phase II. (Fig. 48) shews the lateral movement of the right leg and the right foot touching the ground. Phase III. (Fig. 49) shews the equal distribution of the weight of the

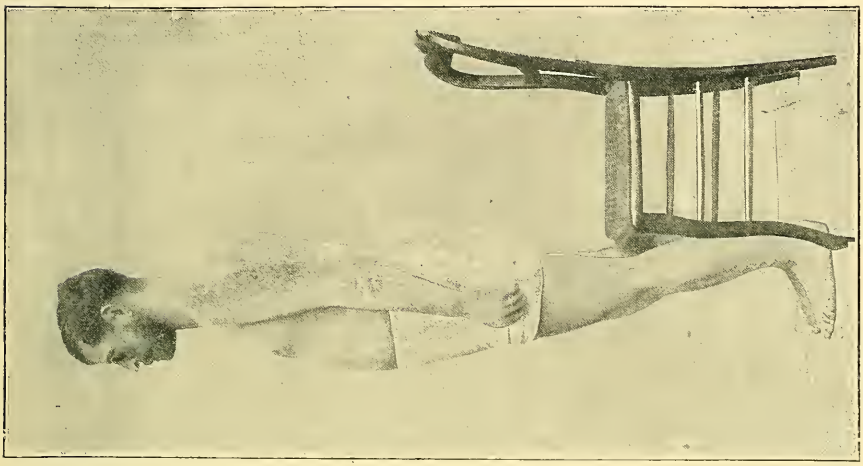

Fig. 58.—Getting up from a Chair. Sixth Phase: The Movement is completed.

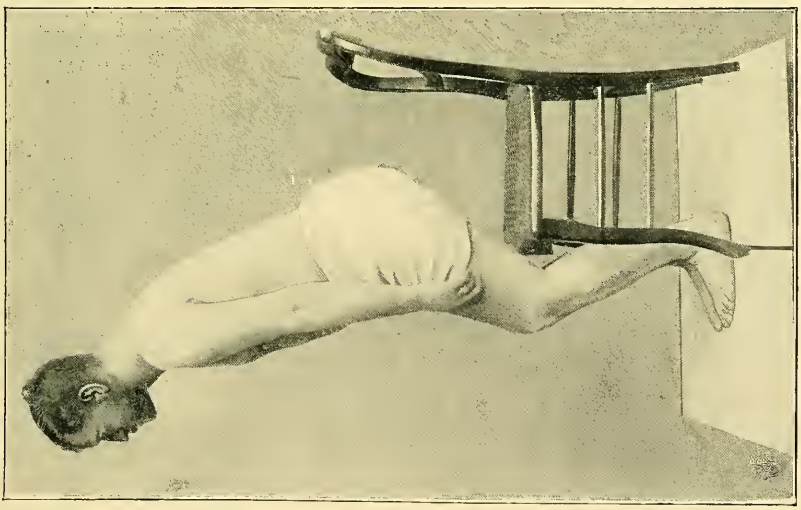

Fig. 57.—Getting up from a Chair. Fifth Phase: Continuation of Movement shewn in Fig. 56.

body on both legs. Phases IV. and V. (Figs. 50 and 51) shew the transference of the weight of the body on to the right leg, in order to set the left leg free. Phase VI. (Fig. 52) shews how the left leg is brought up close to the right and the original position resumed.

Healthy persons, it will be seen from Fig. 48, put the foot on the ground with the toes first, if the step be long enough, so that during the abduction of the leg the foot is plantar-flected; the leg thereby becomes virtually longer, and is thus able to serve as a provisional support before the full weight of the body rests on it, when the heel is lowered and brought to touch the ground. The participation in the lateral movement of the plantar-flexed foot makes even long steps perfectly secure. The shorter the step, the less necessary does this plantar-flexion become; in very short steps it does not take place at all. We shall see later on that lateral locomotion is soon acquired by tabetics, once they have learnt regularly to transfer the weight of the body to the leg which, for the time, is to remain stationary.

9. **Getting up and Sitting down.**—Figs. 53 to 58 illustrate the various phases of the movement of getting up from a chair of medium height. Fig. 53 shews the initial position; the body leaning against the back of the chair, the legs are stretched forward. Getting up from this position is impossible, even if the body be bent forward, because the centre of gravity would fall some distance behind the heels. The first, and under normal conditions automatic, movement is to draw the legs back (Fig. 54). A healthy person who is not afraid of balancing himself on the balls of the toes will draw his legs so far back that his heels leave the ground and the feet rest entirely on the toes; consequently his body will be bent as far forward as possible, and he will get up in this attitude ready to step out. Our illustrations, however, shew the movement made with both feet resting firmly on the ground, which should be practised by all tabetic patients who shun the muscular exertion and the danger of balancing themselves on their toes. In Fig. 55 the body is being bent forward until the line of gravity falls within the area of the heels. In Fig. 56 the body begins to assume the erect attitude as a result of the contraction of the extensor muscles of the thigh and trunk, whereby the angle between the thigh and leg becomes larger, and the trunk is moved slightly back in order to maintain the balance. Both movements are continued in Fig. 57, and find their termination in Fig. 58. The movement of getting up from a chair is an instructive example of the manner in which a certain voluntary position of the various segments of the body is changed into another, without at any moment endangering the maintenance of the equilibrium. Each phase of this movement is characterized by a certain definite and distinctive relationship between the position of leg and thigh on the one hand, and that of the trunk on the other.

In *sitting down* the various phases are the absolute reverse of those just described. In practising this exercise stress should be laid on the continued anteflexion of the trunk. Figs. 53 to 58 in inverted sequence illustrate the various degrees of this anteflexion.

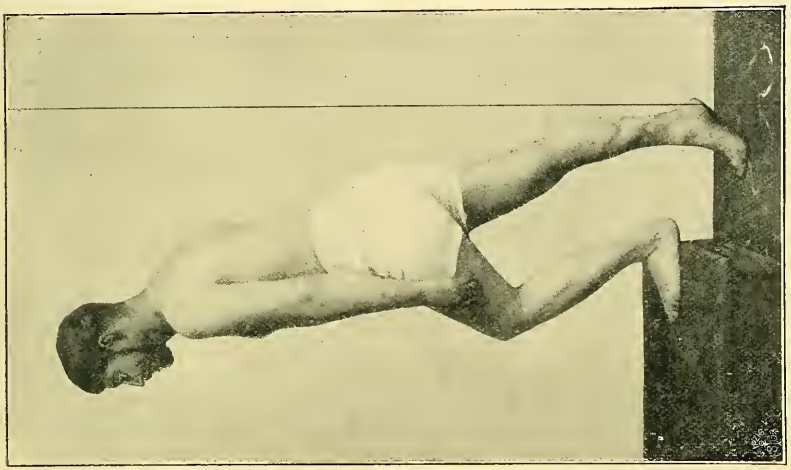

Fig. 60.—Normal Mounting Steps. Second Phase.

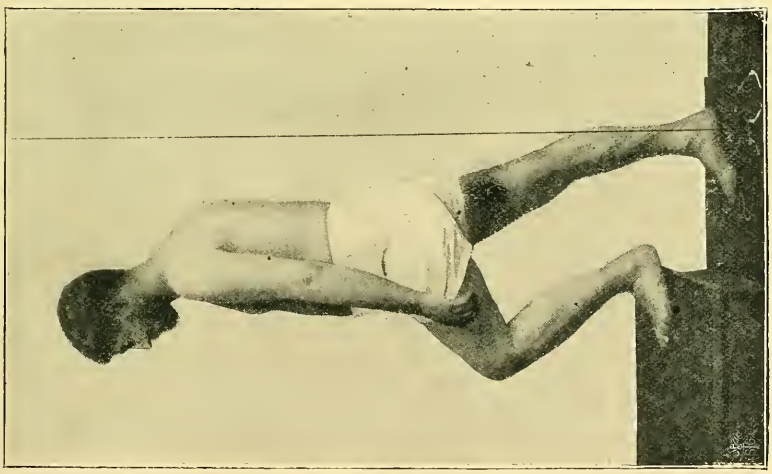

Fig. 59.—Normal Mounting Steps. First Phase.

The trunk has got to be bent far forward in order to avoid "falling" into the chair, an anomaly which is the rule in locomotor ataxy.

10. **Mounting and Descending Stairs.**—In mounting stairs the body is lifted on to the next higher step by the contraction of the quadriceps

of the leg which has been previously placed there. It is absolutely necessary that the weight of the trunk should be transferred to the leg that has been put on the higher step; this enables the foot below to lift the heel off the step (Fig. 59). The continuation of the mounting movement necessitates a large degree of anteflexion of the trunk

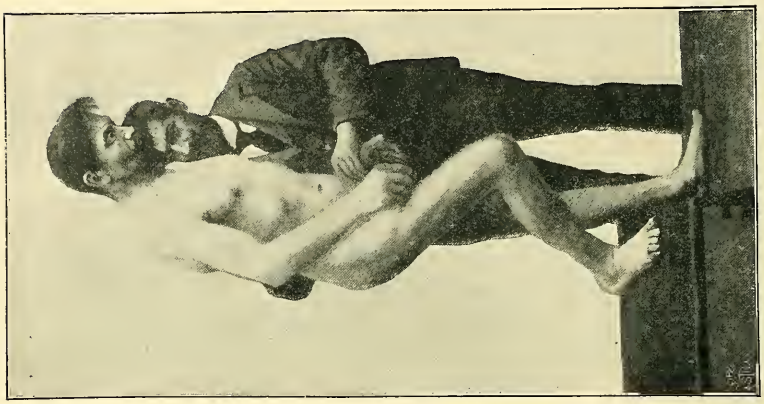

Fig. 62.—Tabes Dorsalis. Descending Steps.

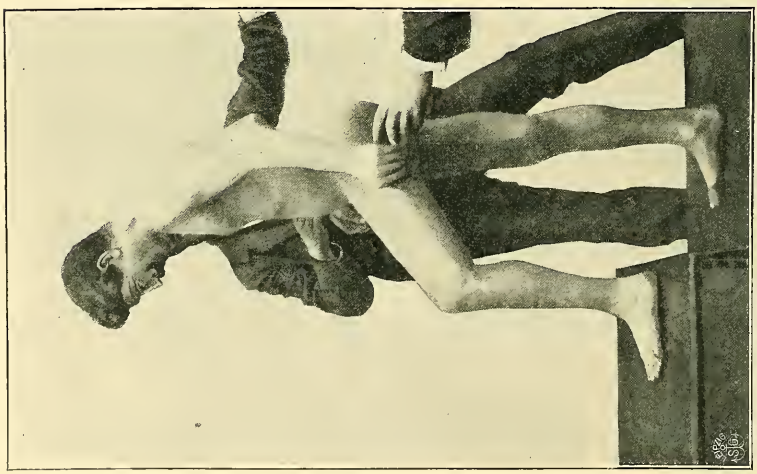

Fig. 61.—Mounting Steps in Tabes Dorsalis. The whole Foot resting on the Step, the Trunk not bent forward.

(Fig. 60); this explains why the ascending foot is put on the step with the ball only, and not with the whole length, because such a large degree of anteflexion of the trunk is only made possible by transferring the centre of gravity to the ball of the foot. The importance of the flexion of the limb in the knee-joint is quite obvious. In

descending, the weight of the trunk is similarly transferred on the descending foot, which touches the step next below with the extended toes ; the body and leg almost " fall " on to the step, the *vis a tergo* in this case being the weight of the body itself. The anomalies observed in tabes during this exercise are very characteristic. The maintenance of the equilibrium of the body during its transference from one toe-ball to the other, the muscular exertion necessary for lifting the body at a moment when it is resting on one leg only, together with the necessity of anteflexing the trunk and letting its weight rest

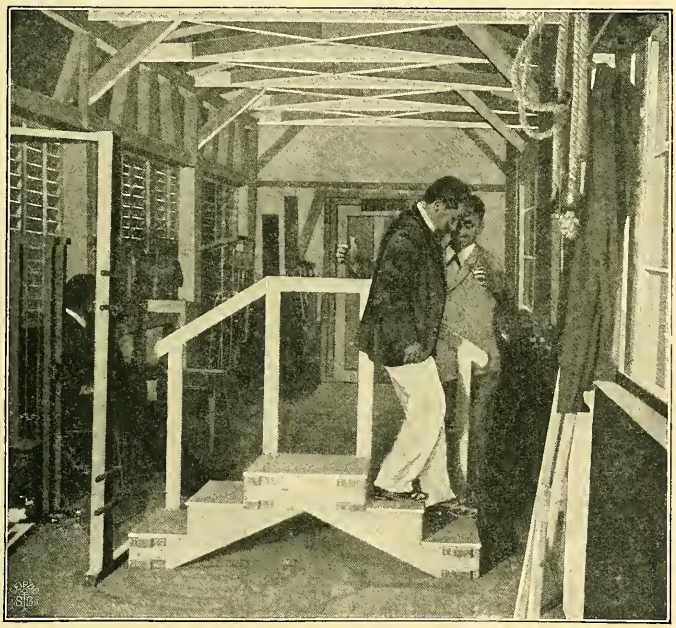

Fig. 63.—Tabes Dorsalis. Walking Downstairs.

on the toes, are such complicated tasks of coordination, that abnormal conditions, however slight, may be recognised quite early in the beginning of locomotor ataxia. These anomalies consist in carefully avoiding to rest the foot on the toe-ball only, which leads to a tendency to use the whole length of the foot, and secondly in a very slight degree of anteflexion of the trunk (Fig. 61). In somewhat advanced cases mounting steps becomes impossible without using the hand-rail or other support. Tabetics descend steps in a characteristic manner that alone is sufficient to establish the diagnosis (Fig. 62). The foot is put down in its whole length, so that the whole width of the step

is occupied by it, and the heel almost touches the vertical surface behind it; the trunk is not allowed to drop on the descending leg, but remains poised on the leg on the step next above, and thus acquires a peculiar oblique position (Fig. 63).

CONDITIONS INFLUENCING THE TREATMENT.

1. **Spinal Irritation.**—Although our treatment should be tried in every case of tabetic ataxia, as it no doubt gives the best results, it is essential that there should be no signs of meningeal irritation of the spinal cord. Spinal irritation may appear at any stage of the disease. It shews itself in constant and dull pain, and paræsthesia of varying intensity, which attack the muscles of the back, and in some cases of the extremities also. The irritation usually lasts some weeks, and is often combined with a distinct increase of the loss of sensation and quasi-paralytic condition. Applying the exercise treatment while this symptom is present is distinctly to be warned against. Lancinating pains are no contra-indication to this treatment; one has only to wait until such crises are over before again beginning the exercises. Quite a number of our patients have told us that they consider the execution of a series of exercises an effective means of warding off or curtailing a painful crisis.

2. **Blindness.**—The optic sense is the greatest supporting factor in the movement treatment, and the question arises whether this treatment should be applied in the case of tabetic patients who have lost their sight. In this connection we have to mention two interesting facts which have not yet been sufficiently explained, namely, that tabetics who lost their sight at an early stage of the disease seldom develop much ataxia, and that developing blindness is accompanied by a marked improvement of the ataxy already present. In cases with partial loss of articular and muscular sensation, there is a large enough residue of sensibility left to insure the success of the treatment; very severe ataxia, however, coupled with blindness and almost complete loss of sensation, hold out no promise of improvement by whatever treatment might be adopted.

3. **Hypotonia.**—Moderate degrees of hypotonia do not adversely influence treatment by exercises; but a severely hypotonic condition, especially of the knee-joints, may necessitate the correction of the faulty position of the joints by means of orthopædic appliances, previous to the commencement of the exercises.

4. **Heart disease** does not exclude treatment by exercises, but

demands great care with regard to the selection and duration of the exercises. The control of the pulse, which should be exercised in every case of tabes, should under no condition be omitted here. A patient with heart disease must under no pretext whatever be allowed to resume his exercise before his pulse has returned to the usual rate of beats. Patients with a weak heart often declare that they do not feel tired simply because they have lost all sensation of weariness.

5. **The Control and Protection of the Patients during the Treatment.** —Tabetic patients who move about without support are liable to a number of dangerous accidents. The greatest danger is due to the fact that they are apt to fall down unexpectedly and as if struck by lightning. It is a common occurrence that a tabetic subject is seen standing quietly and without moving, when he suddenly falls to the ground without having shewn the least swaying or even uttering a sound ; this happens even with patients who always have an attendant by their side. The physiological reason for this collapsing of tabetic persons is a sudden giving way of both knees, which ordinarily are in a position of genu recurvation ; if from some cause or other the knees happen to get into a slightly flexed position, a very easy thing considering that there is always more or less loss of articular sensibility, the equilibrium of the body is suddenly disturbed, and the patient collapses without having had the slightest warning of what was going to happen. One of our patients, an energetic man who had been greatly emboldened by the rapid and great progress he was making, got out of bed during the night and tried to stand up with his feet together. Suddenly he found himself lying on the floor without having had the slightest sensation of falling. Apart from injuries, which are rather frequent, accidents of this kind have always a very unfavourable result on the further progress of the patient, even if he was not injured.

The patients cannot go through the simple movements required in everyday life without great exertion and attention. If they are then set special tasks which require close attention to every detail, and the patients have not the most absolute faith in their protection from accidents, the result is that they try to protect themselves by means of exaggerated contractions of their muscles, producing great exhaustion and mental excitement. How ominous the indirect results of such an accident may be for the patient, may be seen from the fact that not a few tabetic patients date the absolute loss of their ability to walk unaided from an accident of this kind. Insufficient will-power and the knowledge that he cannot trust his own limbs, or even the

support of an attendant, make such a patient forego walking altogether. Muscular inactivity and the absence of exercise, which is the best defence against the increasing loss of coordination, do the rest, and we find that such patients have been keeping to their bath-chairs for twenty and more years simply because at the outset of their tabetic career they had met with an accident of the kind just mentioned. Accidents must be rigorously guarded against, both in the private houses of the patients and in the homes which devote themselves to the reception of tabetics. It is advisable during the exercise to let severe and moderately severe cases be supported by an attendant on either side, and slight cases by one attendant only, and to allow only very slightly ataxic patients to practise without special support by an attendant. There are patients who ask for a third attendant, who then has to guard them against pitching forward.

Proper supervision of a tabetic patient during an exercise is by no means an easy task. The attendants must be intelligent persons who, without touching the patient, must raise in him the confident belief that an accident is absolutely impossible. It is very tiring work, because the incalculable suddenness with which accidents do happen demands the closest and uninterrupted attention on the part of the attendant, who must not touch the patient unless he really threatens to lose his balance. Long experience alone can teach the attendant to know the right moment when his interference, which should then be quick and energetic, is demanded. If such be the case, he must get hold of the patient's body under the armpits, but he is not allowed to catch him by the hand or arm, which would not only not prevent the patient from falling, but may produce fractures or dislocations. The attendant should stand by the side of the patient, but at such a distance that he does not come in contact with the patient, or even touch his clothes. The right hand of the attendant, if he is standing to the left of the patient, and *vice versâ*, is held in such a position that at any moment it can catch the patient under the arm; the left hand must be ready to support the right. The attendant must watch closely the lower extremities of the exercising patient, especially when the patient is looking straight in front of him or up to the ceiling (Fig. 64).

A very frequent accident during the exercise is the turning over of the foot, which causes the patient to fall, and often produces even a severe distortion of the ligaments. The hypotonic condition of the muscles and ligaments of the ankle-joint greatly favours the occurrence of such an accident, which, like all accidents that befall tabetics, comes

about suddenly and unexpected. For this reason the patients should be made to wear strong, high, lace-up boots, or leggings with light invisible steel supports, which can be worn over any kind of boot or shoe. The toes of the boots should be broad and square, the soles should be wider than the uppers, not too thin, and, above all, rough. Some patients prefer non-slipping rubber soles. Rubber soles have one drawback: they slip on wet ground; felt soles or soles made of buffalo-hide are preferable.

Walking-sticks should have a firm, conveniently shaped crutch, and at the other end have fixed a broad, rough rubber socket.

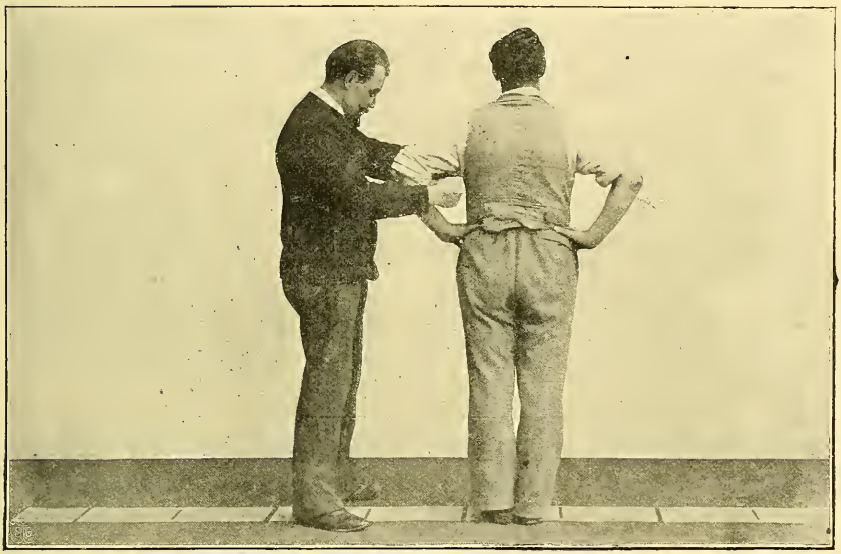

Fig. 64.—Supervision of an Exercising Patient.

Patients who suffer from severe ataxia should be supported by means of a belt (Fig. 65), which is to be worn round the chest, and has several stout handles fixed to it.

The dangers that arise from that tendency to accidents which characterizes the anæsthetic stage of tabes are, perhaps, best illustrated by notes on a few cases:

Case I.—Transverse fracture of the thigh close above the knee. A very strong man, forty years old, tabetic, was ordered by his doctor passive movements in the hip-joint. He was sitting on a chair and crossed his legs; a servant of his clasped the knee of the uppermost leg, and pushing against the hip-joint everted the thigh. During one

of these exercises the thigh-bone snapped across. No pain was felt. Union with large callus and $2\frac{1}{2}$ inches shortening.

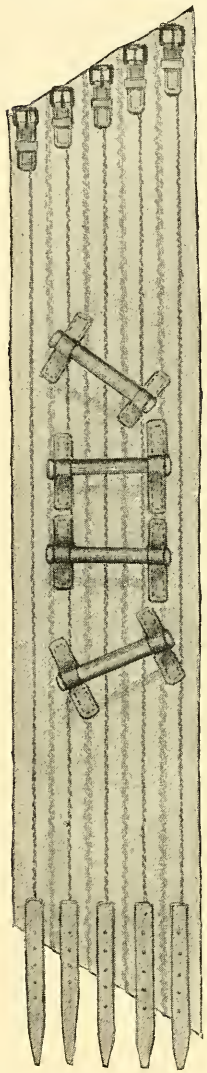

Fig. 65.—Belt for Severe Cases.

Case II.—Tabetic subject, forty-five years old, badly nourished, anæmic; read a report on gymnastic treatment in tabes. A masseur made passive movements, flexing the thigh in the hip-joint with the knee extended. The usually present pain and sensation of tension was in this case almost entirely absent. One day the flexor muscles were partly torn; an enormous hæmatoma was the result.

Case III.—A medical man, fifty-five years old, tabetic, begins a course of "Swedish" gymnastic treatment. After eight days he is unable to stand or move on account of distortion of the foot and severe swelling about the ankle-joint and dorsum of the foot.

Case IV.—A lady, tabetic, forty-eight years old. She walks with difficulty with a stick and the support of an attendant. Active movements with the Zander apparatus; one to two minutes only are spent at each apparatus. After the third sitting the patient has to be carried. She cannot stand, and can hardly move her legs when lying in bed. No change for a few months, then slow improvement under exercise treatment.

The most frequent accidents are fractures, which are often not detected for days, or even weeks, on account of their painlessness; next comes rupture of tendons and distortions. Not infrequent is more or less marked paresis of the lower limbs, especially when the patients are told to make very exhausting and perfectly useless movements with their legs, such as were ordered a patient who was told quickly to draw letters in the air with his legs.

DRESS.

The exercise treatment is tiring to most patients; it raises the pulse-rate and makes the patients perspire. For this reason the patients should wear light garments which do not interfere with or obscure the movements of their limbs. Men may wear their ordinary dress, perhaps without coat and waistcoat. Ladies should, for the beginning, wear a sort of bathing costume until they have learnt to master the movements of their limbs; later they will have to learn to move their lower limbs correctly when wearing ordinary dress.

PRACTICE-ROOMS AND APPARATUS.

The most suitable practice-room and apparatus is that which allows of the simultaneous treatment of several patients. While one party exercises, the other has an opportunity to rest and watch them; thus fatigue is prevented, the heart has time to slow down, and the perspiration becomes normal again. Moreover, the didactic value of seeing the various exercises being gone through by fellow-patients, to whose verbal instruction they can listen undisturbedly without their attention being half occupied by the task of performing these movements themselves, is very great indeed. Lastly, certain movements which are the result of the patients being obliged to make way for one another, or to stop in order to address a few questions to one another, and so on, cannot adequately be gone through when patients are practising alone. As far as treatment in special homes is concerned, the patients who make their exercises in bed should be instructed individually, because the relatively little exhaustive nature of the exercises and the comparatively great sense of security which the patients derive from this position allow them to follow the instructions of the doctor with ease and attention. The exercises in erect posture and walking should be practised in groups of three to six patients all having about the same amount of ataxia. In private practice single patients should be exercised in long and well-lighted corridors. These corridors should not be so narrow that the patients with outstretched arms could touch the walls, because if such were the case the patient as well as the doctor would get a wrong idea of the patient's ability to maintain his balance, which would be roughly dispelled as soon as the patient tried to repeat his exercise in a larger room. The diagrams and other floor-markings which are required for

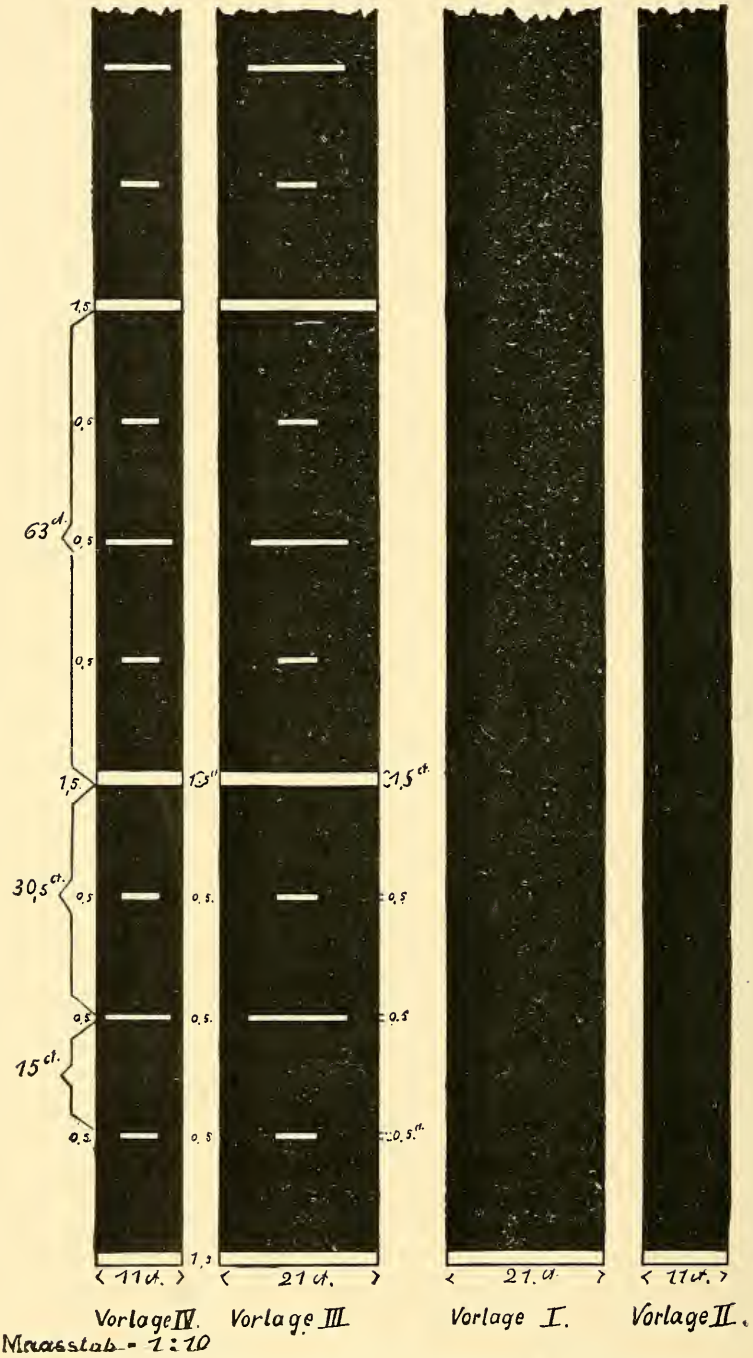

FIG. 66.—Pattern I.; Pattern II.; Pattern III.; Pattern IV.

the exercise treatment should be painted on linoleum, which can be taken up when no longer required.

Size of Practice-Room.—In order to avoid as much as possible during the exercise of the tabetic patients the annoying and very tiresome turning round, the practice-room should have a length of about 25 yards. In severe cases this will be the maximum length which the patient will be able to traverse at a time; but even in slight cases we do not let the patient walk this length more than twice, in order to obviate turning round as much as possible. The room should be so wide that the patient and an attendant on either side of him can comfortably move. There ought to be numerous seats along the walls, so that the patients can sit down after their exercise without being obliged first to walk a long distance to their chair. The seats should have back and arm rests.

Fig. 67.

Diagrams and Other Marks on the Floor.—It is, of course, possible to do without diagrams and other marks on the floor, especially in private practice; on the other hand, it would be a grievous mistake, which would have to be paid for dearly, to employ apparatus with fixed rails and obstacles instead of simple marks painted on the floor. The floor marks which we shall now describe have during many years' experience been found the most appropriate both as regards their size and pattern.

I. A straight black stripe, 9 inches wide, which is about double the width of a booted foot (Fig. 66, Pattern I.) painted on the floor, occupying the whole length of the practice-room.

II. A black stripe similar to the former, but only half its width (Pattern II.).

III. A black stripe like Pattern I., and of the same width, but divided by white cross-lines $\frac{1}{2}$ inch wide into sections measuring 27 inches in length. This is the length of a *full step*. Each section is further subdivided by white lines into half-steps, measuring $13\frac{1}{2}$ inches each, and quarter-steps $6\frac{3}{4}$ inches in length (Pattern III.).

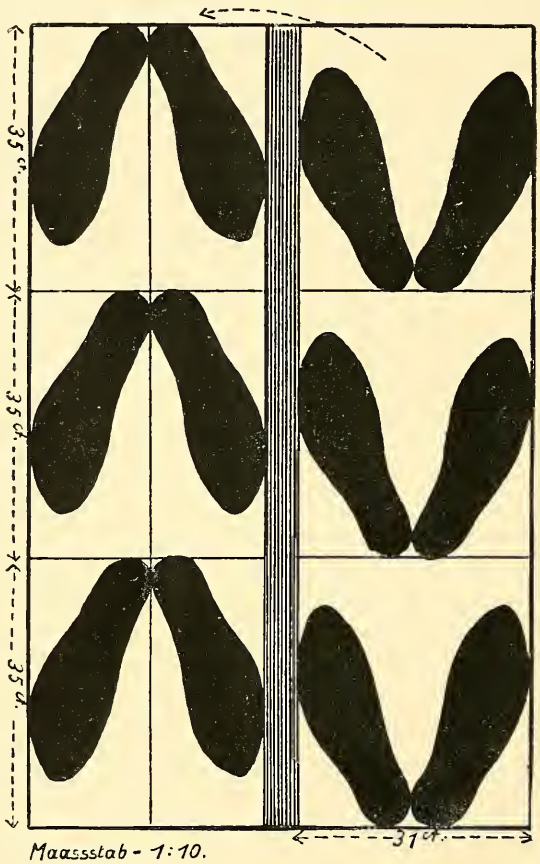

Fig. 68.

IV. A similar stripe as Pattern III., but only half as wide (Pattern IV.).

V. The zigzag (Fig. 67). This zigzag stripe is also $9\frac{1}{2}$ inches wide; the length of its sides is 27 inches, corresponding to the full step.

VI. The footprints. Pairs of footprints are painted on the floor, arranged as in Fig. 68, six to ten pairs in double row, which enable the patient to go through his exercise in both directions.

VII. Diagrams for the instruction in turning round. The diagram on the left shews the patient how to turn to the left, the other is for

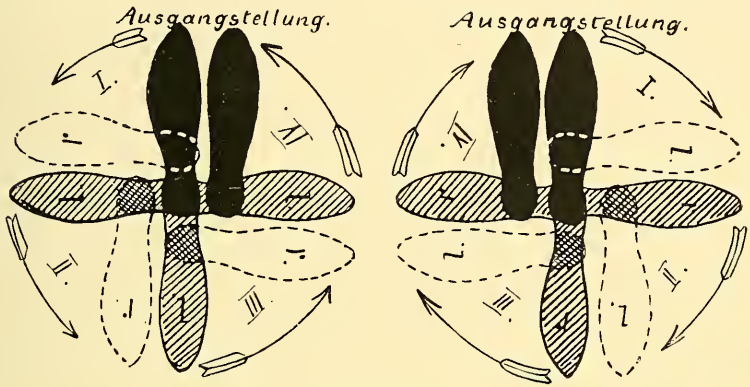

Fig. 69.

the movement to the right. The black footprints signify the initial position. In turning round to the left the movement takes place round an axis, that is represented by the left heel, which turns

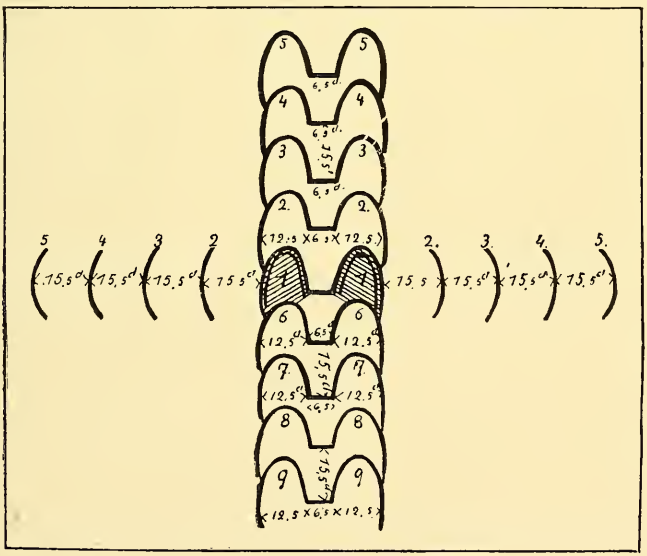

Fig. 70.

round itself without leaving its place. The right foot follows in the manner indicated in the diagram. In turning round to the right the movement takes place round the right heel (Fig. 69).

VIII. The shaded footprints represent the initial position. The distances are given in figures in the diagram, but are of course not inscribed on the floor, but the Nos. 1, 2, 3, etc., to 9, should be painted in large characters on the places shown in Fig. 70. This pattern

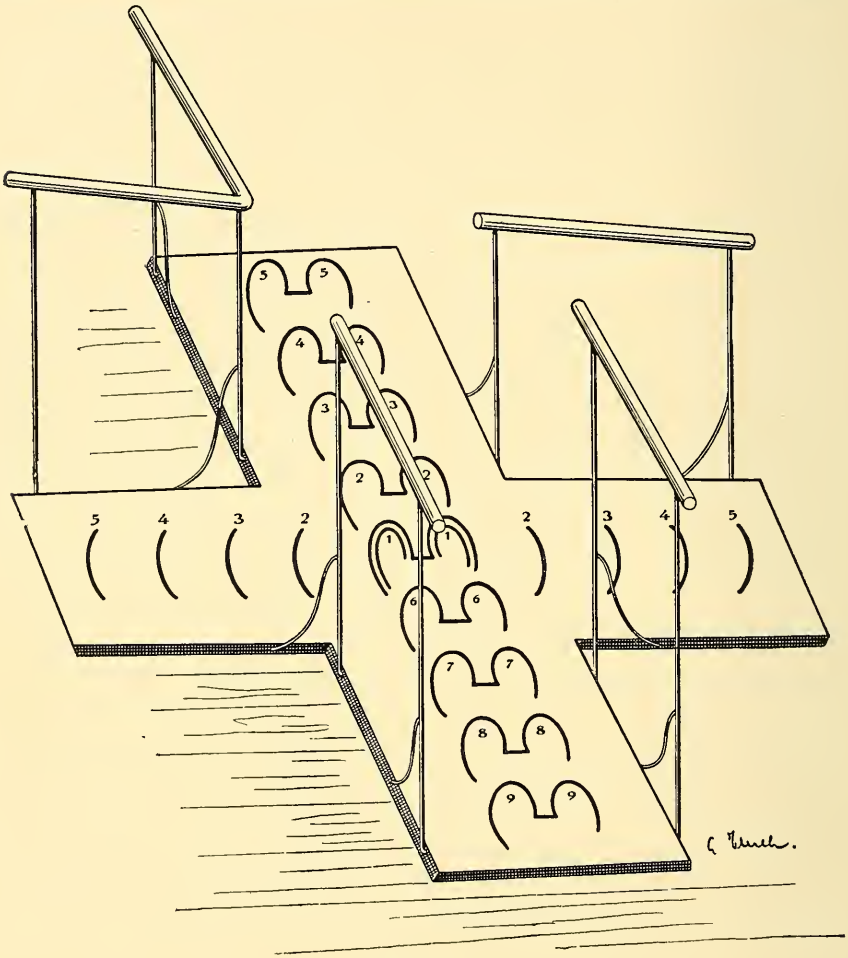

Fig. 71.

serves to instruct the patients in making quarter-steps forwards, backwards and sideways.

IX. The floor-cross. A huge Geneva cross made of deal boards with the diagram (VIII.) painted on it; it has handrails and is portable (Fig. 71). Its use, like that of Pattern VIII., will be fully discussed when the various exercises are described in detail.

Besides these marks on the floor and the floor-cross, we use in special cases some simple apparatus, illustrations of which will be found in another part of the book.

For the re-education of the upper extremities we use a set of apparatus which are designed for the purpose of practising the more delicate coordination of the arms and hands. They will be fully discussed when we deal with the various exercises for the upper extremities. We use also diagrams which the patients have to copy. They are reproduced in various sizes on stout cardboard or light deal board, and are fully illustrated in the description of those exercises.

CLASSIFICATION OF EXERCISES.

The exercises may be classified according to the various functions of the affected limbs, and according to the manner and degree of ataxy.

The exercises for the lower extremities, and those for the trunk and the upper extremities will have to be put in separate groups. The lower extremities, whose work is chiefly locomotion, must be treated differently from the upper limbs, which have to perform an enormous number of complicated movements of relatively small amplitude. As regards the various degrees and forms of ataxia, the difference which often exists in the ataxia of both arms or legs makes it obligatory upon the medical man to choose the exercises which are most suitable in each case, and to adapt their sequence, duration and intensity to the requirements of each individual case.

I. THE LOWER EXTREMITIES.

The exercises for the lower extremity are divided into :

1. Those that are practised in a recumbent position—*i.e.*, in which the influence of gravitation and the necessity of keeping the equilibrium may be eliminated.
2. Those that take place when the patient is in a sitting position.
3. Those that are executed by the patient in an erect position.
4. Those which consist in various movements and evolutions carried on during walking.

A. Exercises for the Recumbent Position.

The following rules should be observed at these exercises : (*a*) The movements are to be continued until the maximum excursions are reached, *i.e.*, the smallest possible angle for flexion and adduction and

the largest possible angle for extension and abduction. (*b*) The heel has throughout the exercise to rest on the couch or bed, and slides over it backwards and forwards. The magnitude of the angle between thigh and knee is the precise expression of the excursions of the lower limb (Fig. 72). (*c*) The eyes are to be kept open, and should follow the movements with great attention.

The Exercises.

The patient is lying on his back, the body resting on a low, wedge-shaped bolster, the head raised so that the patient can watch every movement. The initial position from which each exercise starts is the following: Both lower limbs are stretched out and in apposition to one another; they must return to this position at the conclusion of every exercise.

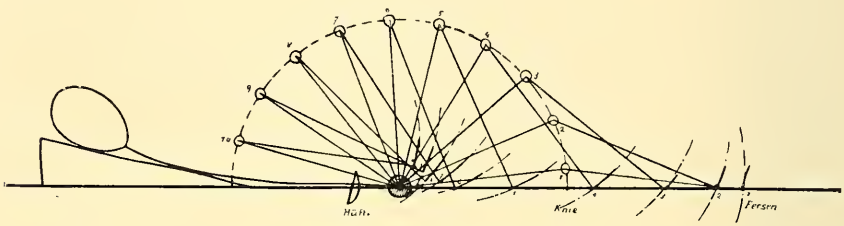

FIG. 72.

The following are the most frequently required exercises:

1. Flexion of one lower extremity (hereinafter called "leg") in the knee and hip joints—extension.

2. Flexion of one leg in knee and hip joints, abduction of flexed leg, adduction of flexed leg—extension.

3. Flexion of one leg in knee and hip joints, but only to one-half the angle—extension.

4. Flexion of one leg in knee and hip joints up to one-half of angle (as in 3), abduction, then adduction—extension.

5. Flexion of one leg in knee and hip joints, a voluntary halt to be made during flexion by the patient—extension.

6. As in 5, with this modification, that the halt is called by the doctor.

7. Flexion of one leg in knee and hip joints—extension, a voluntary halt being made by the patient during extension.

8. As in 7, but the halt is called by the doctor.

9. Both legs are simultaneously flexed in knee and hip joints—extension.

10. Flexion of both legs in knee and hip joints, abduction, adduction in flexed position—extension.

11. Half-flexion of both legs in knee and hip joints—extension.

12. Half-flexion of both legs; abduction and adduction in this position—extension.

13. Flexion of both legs; a voluntary halt made by the patient during flexion—extension.

14. Flexion of both legs; halt called by the doctor during flexion—extension.

15. Flexion of both legs in knee and hip joints—extension; voluntary halt made by the patient during extension.

16. Flexion of both legs in knee and hip joints—extension; halt called by the doctor during extension.

Tempo.—The tendency which all patients have of making the movements rapidly must be overcome by energy and patience; the movements should be made as slow as possible; the greater the progress made by the patient, the slower the movement will become. The movement should be even, not jerky at first and slower afterwards, or *vice versâ*. At the commencement of the treatment all movements will be made "staccato."

Repetition.—No exercise should be repeated more than four times in succession, in order to keep the attention of the patient fixed on it. It is better to practise the legs in turn; if, as is frequently the case, one leg is more ataxic than the other, the leg that is worse should be exercised more frequently.

Position of the Practising Leg.—Next to moving slowly, the most difficult task seems to be to keep the leg moving in a vertical plane; there are often most violent lateral oscillations; when being abducted the leg simply drops outwards; many severe cases have the tendency to bend the foot plantarwards. We have seen that normally, when the knee is bent, the toes are raised; from this reason and because the hypotonia of the ankle-joint must under all circumstances be opposed, the patient should be asked at the beginning of each exercise first to dorsiflex his foot, and to keep it so flexed throughout the exercise.

Magnitude of Excursions.—The angles with which we have to deal are one between thigh and leg, another between pelvis and thigh, and a third between the thigh and the level. In normal persons the angles are limited by the resistance of the ligaments of the capsules of the

joints and the muscle tone. In locomotor ataxia we have seen that the muscle tone is lost and the capsules become flaccid, and as a consequence the possible excursions of the joints become larger. The thigh can then be flexed upon the pelvis until the angle is reduced to 10, or even 5, degrees instead of 20; the flexed and abducted thigh rests on the bed instead of stopping some 5 inches above it. On no account must the movement be continued until the maximum amplitude is reached, lest the capsules and muscles be still more relaxed; the movements must take place within the normal limits. When one leg is flexed, its heel should be brought close to the knee of the other leg, not higher up. When both legs practise together, they should lie side by side without touching one another; the knees are to be held at the same height during the exercise.

The heel should slide up and down on the bed or couch; the patient should lie on a smooth linen sheet, or in summer, at any rate, on oil-cloth.

The patient who has to lie on his back during the first exercises from the beginning of the treatment practises two joints—namely, the hip and knee joints—because in the position occupied they are the simplest and easiest to practise; he cannot yet practise movements while lying on his stomach, because he has not yet learnt to dispense with the control of his movements by his eyes.

Further Exercises.

17. Flexion of one leg in knee and hip joints—extension; the heel is not allowed to slide on the bed, but should be kept some inches above it.

18. One leg flexed until its heel can be brought to rest in the groove between the patella and thigh of the other—extension.

19. The heel of one leg is brought to rest on the top of the patella of the other—extension (Fig. 73).

20. The heel of one leg touches the other leg above the patella, voluntary halt made by the patient—extension.

21. The same as in 20, but the halt is called by the doctor—extension.

22. The same as 19, a voluntary halt being made by the patient before extension.

23. The same as 19, but the halt is called by the doctor—extension.

24. The same as 19, but the heel touches the middle of the tibia instead of the patella (Fig. 74).

25. The heel touches the middle of the tibia, a voluntary halt being

made by the patient; the leg is then flexed in the knee and hip joints and extended.

26. The same as 25, but the halt is called by the doctor.

27. The heel touches the ankle of the other leg—extension.

28. The same as 27, a voluntary halt being made before extension.

Fig. 73.

29. The same as 28, but the halt is called by the doctor.

30. The heel is put on the toes of the other foot—extension (Fig. 75).

31. The same as 30, with a voluntary halt before extension.

32. The same as 31, the halt being called by the doctor.

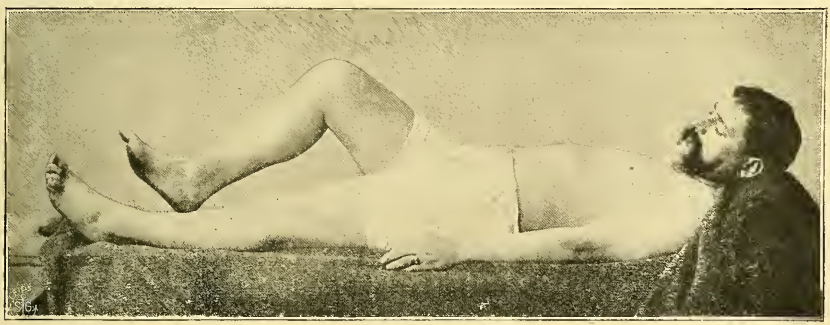

Fig. 74.

33. The heel is first put on the patella on the other side, then raised and put on the middle of the tibia, lifted off again and put on the ankle-joint, and finally on the toes.

34. The same as 33 in inverted order.

35. Flexion of leg as in 1; the heel is then put on the patella—extension.

36. The leg is half flexed; the heel then touches the middle of the tibia—extension.

37. The leg is brought into one-quarter flexion until the heel rests on the ankle-joint on the other side—extension.

38. The heel is brought to rest on the toes of the other side; the leg is then flexed in the knee and ankle joints—extension.

39. The heel is put on the knee of the other leg, then lifted off and put down close to the other knee—extension.

40. The heel is put on the middle of the tibia, then lifted off and put by the side of the leg—extension.

41. The ankle-joint of the other foot is touched with the heel, the leg then flexed in knee and hip joints, and the foot put down on the bed—extension.

Fig. 75.

42. The heel rests on the toes of the other foot; the leg is then flexed in the hip and knee joints, the foot put down on the bed—extension.

43. The heel is put on the other knee, thence on the bed by its side; the leg is then extended until the heel touches the middle of the tibia; the heel is then put on the bed close to the other leg, extended until the ankle-joint can be touched, another rest first on and then by the side of this joint—extension.

44. The same as 43, but in inverted order.

Remarks on Exercises 17 to 44.

The chief characteristic of this set of exercises is that the heel of the exercising leg is not allowed to rest on the bed, as in the former series, when muscular force had to be saved. Exercise No. 17 is intended to *combine the balancing of the quasi-suspended limb with the performance of movements in the joints.* This combination at first

causes the patients great exertion. This tendency to exaggerated movements leads them to raise the heel unduly high. The patients often perform characteristically dissociated combinations of muscular contractions when practising this exercise, such as extreme flexion of the thigh on the pelvis followed by extension of the knee-joint, whereby the heel is lifted off the bed, after which the extended limb is allowed to fall back on the bed. By means of such dissociated muscular contractions, the patient solves the task of extending the flexed lower limb without letting his heel slide up and down on the bed. Normally this movement is made by *simultaneously* enlarging the angles between the pelvis and thigh, and between the thigh and leg.

A still more difficult task of coordination is the occupation of medium positions, such as are required for Exercise No. 27 *et seq.* When the lower extremity is flexed in the hip and knee joints until the anatomically possible limit of flexion is reached, it often shews a tendency to fall outwards if a halt is made with the heel at a level with the middle of the tibia or the ankle-joint of the other leg. This fact may be explained by the law which applies to all tabetic subjects, namely, that movements requiring a maximum of muscular contraction producing small angles at the joints are easier to make than slight movements producing large angles. The reason for this phenomenon is furnished by the endeavour of the patient to compensate his loss of muscular sensibility by means of making exaggerated contractions. Exercise No. 22 repeats the usual test for ataxia (heel to knee movement). Nos. 18 and 19 are easier, as there the heel has more support. The tendency to abduct the flexed thigh must be resisted.

Special attention should be paid to the more or less prolonged fixation of the leg in a certain indicated position. This practice of "static coordination" demands at every moment qualitatively and quantitatively constant innervation and great attention; the heel should be supported during this exercise, which is intended to prepare the patient for practising standing.

Exercises Nos. 33 and 34 demand a very slight, but accurately defined, additional contraction; they require, therefore, a relatively large amount of coordination, because the slightest jerk of a muscle frustrates the purpose of the movement. The large angle between the thigh and leg, in addition to the short distance to be traversed by the heel, makes exercise No. 40 especially difficult.

Exercises.

45. The patient puts his heel on the knee; the heel then slides along the tibia down to the ankle-joint—extension.

46. The same as No. 45, but the heel, instead of stopping at the ankle-joint, slides along the crest of the tibia back to the knee-joint.

47. The patient puts his heel on the knee; the heel then slides along the tibia to the toes—extension.

48. The same as No. 47, but the heel travels back along the tibia to the knee-joint.

49. The heel rests on the knee, then slides along the tibia, stops in the middle of it, then continues until the ankle-joint is reached and stops again, then continues to move down to the toes—extension.

50. The same as No. 48, but the interposed halts are called by the medical man who supervises the movement.

Remarks on Exercises 45 to 50.

The value of these exercises for the re-education of coordination consists in making the patient balance the heel on the narrow edge of the tibia, and in continuously changing its position. This necessitates accurate coordination of the whole of the muscles of the thigh, leg, and foot, lest the heel slip off the edge of the tibia. The ever-varying degree of accuracy with which the patients perform this movement adds great interest to the study of these exercises. If, as in Exercise No. 47, the heel is to be enabled to reach the toes of the other foot, the latter must be flexed in the knee-joint.

In Exercise No. 49 the heel of the extended leg rests on the toes of the other leg; it can occupy this position only by means of the support it receives from the whole of the muscles of the limb by which the leg is kept in this difficult position. The principle which underlies these exercises is: *a maximum of coordination combined with a minimum of muscular contraction*. Exercises which combine a relatively easy task of coördination with a large amount of muscular contraction are not only useless, but even detrimental.

Exercises.

51. The lower limb is flexed in the hip and knee joints until the leg forms a right angle with the thigh—extension.

52. The knee-joint is kept extended, and the limb is first flexed in the hip-joint (foot slightly dorso-flexed), then slowly extended.

53. The same as 52, the limb is then flexed as in 51—extension.

54. The same as 51; the knee is then extended, and the limb slowly lowered on the bed.

Remarks on Exercises 51 to 54.

In each of these exercises the lower limb is at a certain moment held unsupported in the air. This act requires even in healthy people a considerable amount of muscular strength, which must needs be still larger in tabetics for reasons already discussed. On the other hand, the task of coordination is slight, owing to the absence of precise limits. These exercises should, therefore, be only occasionally gone

Fig. 76.

through, and not be continued long. To hold the lower limb up in the air for any appreciable time is most injurious, especially when the sensation of fatigue is much reduced or entirely absent. In flexing the stretched lower limb in the hip-joint, care should be taken not to hyperextend the flexors at the back of the thigh.

Exercises.

55. Both lower limbs are to be flexed in such a manner that both knees and inner malleoli remain in apposition—extension.

56. Both lower limbs in close apposition are to be half flexed, then extended.

57. As in No. 55, but two or three voluntary halts should be made.

58. As in 57, but the halts are called by the doctor.

59. Both limbs to be flexed; one remains flexed, the other is extended, and *vice versâ;* then both are flexed, followed by extension.

60. As in 52, but in extending the limb the heel should not touch the bed, but be kept a short distance above it.

61. As in 59, but during flexion the heel should not touch the bed.

62. As in 59, but both movements are to be performed so that the heels do not touch the bed.

63. Both limbs are to be flexed and extended, but the heels must not touch the bed.

64. Both limbs are flexed in hip and knee joints, the heels not touching the bed—extension.

65. As in 64, but the heels are to be kept off the bed during extension also.

Fig. 77.

66. Exercises 59 to 65 are to be complicated by keeping the knees and heels in close apposition (as in 55).

67. One limb to be flexed in the usual manner; while it is being extended, the other is first flexed, then extended.

68. One limb first flexed, then abducted while the other is being flexed; the abducted leg is then adducted while the other is being extended—extension of adducted leg.

69. One limb is first flexed, then extended; the other is being abducted while resting on the bed—adduction.

70. One limb is flexed while the other is being abducted—extension of the flexed, adduction of the abducted limb (Fig. 77).

71. As in 67, with this complication, that the heel does not touch the bed while the limb is being extended.

72. One limb is flexed in hip and knee joints, then abducted, while the other is being flexed; then the first limb is adducted, while the

second is extended without touching the bed; lastly, the first limb is extended without resting on the bed (*cf.* 68).

73. One knee is flexed in knee and hip joints, then extended

Fig. 78.

without touching the bed, while the second is first abducted and then adducted (*cf.* 69).

74. One limb is flexed in hip and knee joints, while the other is

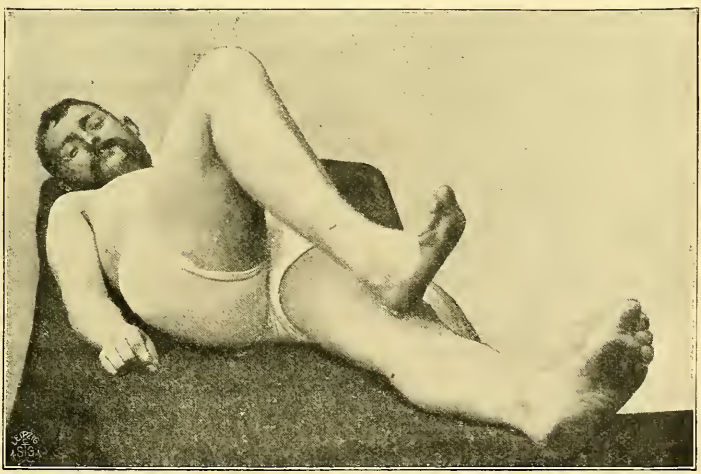

Fig. 79.

first abducted, then flexed; both limbs are then brought together and extended without touching the bed (*cf.* 70).

75. A combination of Exercises 57 to 70, with this complication,

that during flexion the heel of the moving leg does not touch the bed at all.

Remarks on Exercises 55 to 75.

Exercises Nos. 55 to 59 inclusive introduce a new means of controlling movements, namely, the sensibility of the skin. The patient should try to move both lower limbs simultaneously, and at the same time he should carefully study the tactile impressions which are caused by these movements. How far this control of the movements should be exercised by the patient has to be decided by his medical man, who should have due regard to the loss of sensation.

Whenever an exercise comprises a phase when a limb is to be moved so that the heel does not touch the bed or couch, a short rest should be taken after each phase of the movement, and not only at the end of the exercise, for it is necessary to spare the strength of the muscles.

In the Exercises 59 *et seq.*, *both lower limbs perform different movements at the same time.* It becomes at once apparent that movements which have previously been well performed by each limb become extremely difficult when they have to be made by both limbs together. The tendency of the tabetic patients to transform continuous movements into successive staccato movements becomes very obvious during these combined exercises; one moment they move one limb, in the next the other, and so on. A perfectly analogous condition exists in healthy people who are called upon to perform unusual and bilaterally different movements, such as tapping on a table with one hand while the other makes brushing or rubbing movements.

The exercises should be so varied that each limb has its proper share of attention and practice. The medical man should not forget that generally the degrees of incoordination in either limb differ.

Exercises.

76. The heel is to be placed on the knee of the other leg; it then follows the course of the tibia down to the ankle, but, without touching, stops above the ankle for awhile, and then travels back to above the knee, another halt—extension (*cf.* Fig. 45 *et seq.*).

77. As Exercise No. 76, with this difference, that the movement is continued as far as the toes.

78. The heel is first placed on the knee; it is then raised and placed on the upper, the middle, and, lastly, the lower third, a short halt being made after each successive movement; the heel then moves back in reversed order—extension.

79. The medical man places the tip of one of his fingers on various places of the leg; the patient tries to put his heel exactly on the finger (Figs. 78, 79).

80. This exercise begins like the previous one, but at the moment the patient tries to put his heel on the finger, the medical man shifts

Fig. 80.

his finger to another place, and the patient must try to follow its course without touching it. At first one effort at localization is sufficient; later in the course of the treatment quite a number of "guesses" may be made (Fig. 80).

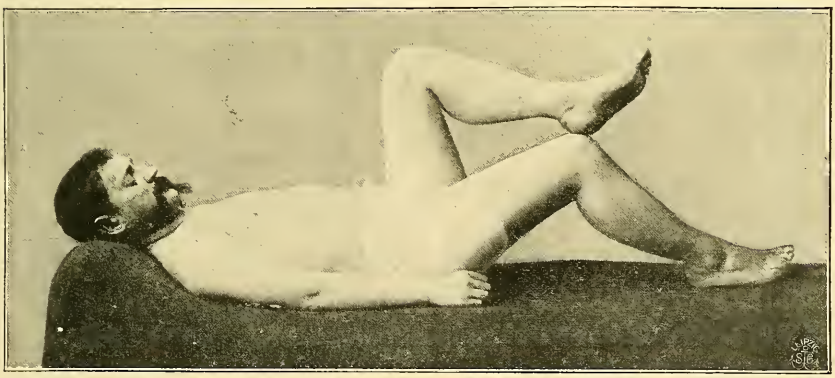

Fig. 81.

81. The patient tries to place his heel into the hollow of the doctor's hand, which constantly changes its position (Fig. 83).

82. The heel is put on the knee of the other limb, which is lying extended on the bed; while the heel is resting on the knee, the

extended limb is flexed in the knee-joint and then again extended (Fig. 81).

83. The heel is placed on the middle of the leg; the rest like No. 82 (Fig. 82).

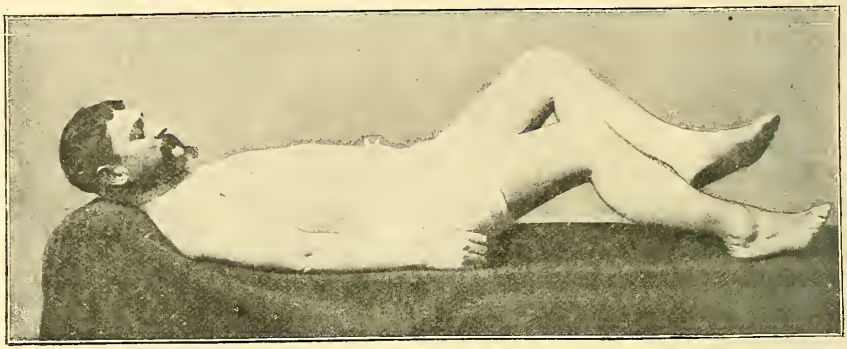

Fig. 82.

84. The heel is placed on the knee of the extended limb; while the latter is being flexed and extended, the former is abducted and adducted (*cf.* Fig. 79).

85. Both limbs are flexed; then one is extended with the heel sliding on the bed, the other without touching the bed.

Fig. 83.

86. One limb is flexed without touching the bed, the other is flexed in the hip and knee joints without touching the bed, then extended, followed by extension of the first leg.

87. One limb is flexed while the other is being extended and abducted; the former is extended, while the latter is adducted without being flexed or raised.

88. The heel is placed on the knee of the other limb; while it is sliding down the tibia the limb supporting it is flexed; the heel then travels back towards the knee while the flexed leg is being extended.

Remarks on Exercises 76 to 86.

With regard to the Exercises 76 and 77, it should be remembered that it is much more difficult to flex than to extend the leg while it is being held in a raised position above the tibia of the other leg.

In Exercise 78 the practising leg tries to touch certain points which the patient himself selects, while in the following and more difficult exercise the heel has to touch the spots which the doctor indicates. This group of exercises completes the system of coordination exercises, which are to be gone through in the prone position. Of course, they may be infinitely varied, their tempo quickened, and so on. Remembering that every coordinated movement is the more difficult the smaller its amplitude, the doctor by shifting his finger a very short distance only can put the patient's coordination to its severest test. Exercise No. 80 teaches the patient momentarily to interrupt the execution of an intended movement, and to convert one movement into another as the necessity for so doing arises. The precision of the movements of a limb, as well as of the whole body, depends in the healthy subject on the ability, which can only be acquired by practice, to cease an intended movement at a moment's notice, or to convert it into another movement. In tabetic subjects, however, this faculty is the one of all others that is first lost, and in consequence of the loss of which all their movements become unsteady. This series of exercises, therefore, comprises the most important coordination tests, based on the principle of *a maximum of coordination with a minimum of muscular exertion*. When incoordination is only slight, or in the so-called preataxic stage, these exercises should be the ones that are principally gone through with the patient.

Exercises 81 to 88 continue and vary the series of different double movements; they are arranged so that each subsequent exercise is more difficult than the preceding one. The medical man who superintends the movements should take care not to overexert the patient.

Exercises for Extreme Ataxia (the So-called Paralytic Stage of Tabes Dorsalis).

In the general part we have endeavoured to prove that tabetic patients who are suffering from an extreme degree of ataxia, in spite

of their inability to perform voluntary movements, are by no means paralyzed in the ordinary acceptance of the term, because it is possible for them to acquire again the faculty of performing incoordinated movements, which are subject to further improvement if properly treated. Such cases require special care and attention on the part of the medical man as well as the patient. Proper coordination exercises are of no use at this stage of the disease, when the patient is "practically paralyzed." *These exercises, however, are justified, and extremely useful from the moment when proper treatment has made the limbs again ataxic.* For this purpose we employ simple contractions in single muscles or groups of muscles which have the same function, limiting the movements as much as possible to one joint. The exercises are divided into four groups, namely, exercises for the toes, the foot, the leg, the thigh.

1. *The Toes.*—Flexion; extension; adduction; abduction of one toe or of more, or all.

2. *The Foot.*—Plantar flexion, dorsal flexion; raising the outer edge of the foot; raising the inner edge; rotation of the foot in the ankle-joint.

3. *The Leg.*—(The patient sitting up with his legs hanging over the edge of the bed.) Extension and flexion of the leg.

4. *The Thigh.*—Inward rotation; outward rotation; abduction and adduction (the limb resting on the bed during movements); crossing the legs.

Remarks to Exercises 1 to 4.

(1) Isolated movements of the toes are generally very rudimentary, even in healthy persons; systematic movements of the toes are nevertheless very important, because in the course of tabes one often sees develop an anomalous position of the toes, which consists of hyperextension of the first phalanx and hyperflexion of the second, respectively the second and third phalanges.

(2) Tabetic pseudo-paresis of the peronei muscles producing ankle-drop is very common, and emphasizes the necessity for carefully exercising the muscles, which produce the movements of the foot.

(3) For these exercises, the patient should sit up and let his legs hang over the edge of the bed, and it is important to eliminate movements in the hip-joint. It must be kept in mind that extending (raising) and flexing (lowering) of the leg are produced by the same group of muscles, viz., the extensor quadriceps cruris; the flexion

of the leg is the result of the prevalence of the weight of the leg over the contraction of the extensor. Isolated contraction of the flexors of

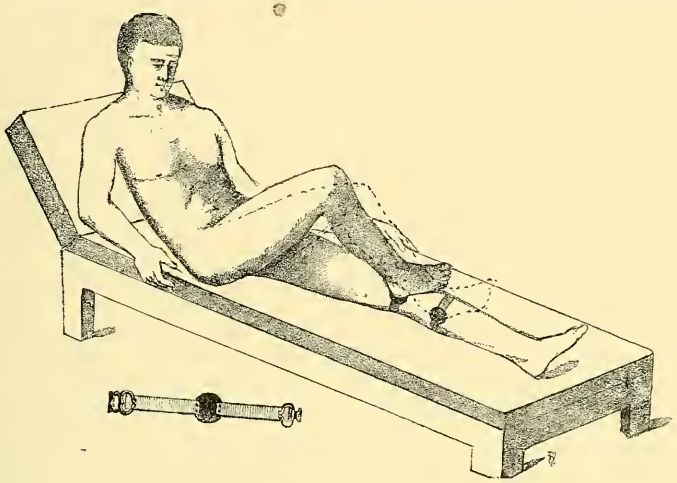

Fig. 84.

the leg should not be practised just yet, for it requires that the patient should either lie on his stomach or make passive resistance, both conditions which the patient cannot yet fulfil.

(4) In practising rotation of the thigh, the medical man should be *careful to avoid excessive outward rotation*, on account of the pronounced hypotonic condition of the muscles, which normally produce inward rotation. These muscles may be easily overstretched ; as it is, the outer edge of the foot is often seen to rest on the bed.

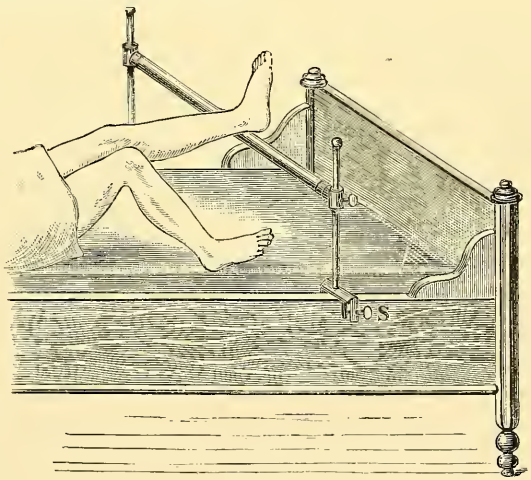

Fig. 85.

(5) Most of these exercises are very tiring and exciting to the patients, and the medical man will do well to make the exercises short,

to support the movements with his hand, and to control the pulse of the patient.

Exercises in Bed with the Use of Special Apparatus.

89. An elastic garter, to which a circular disc of about 2 inches diameter is fixed, is put on just below the knee, and its position continually changed, while the patient tries to touch the disc with the heel (Fig. 84).

90. A round wooden cross-bar, which is so connected with two uprights that it may be raised or lowered, brought nearer to, or moved away from, the patient, is fixed to the sides of the bed as shown in Fig. 85. The patient is told to put his legs alternately on the bar and

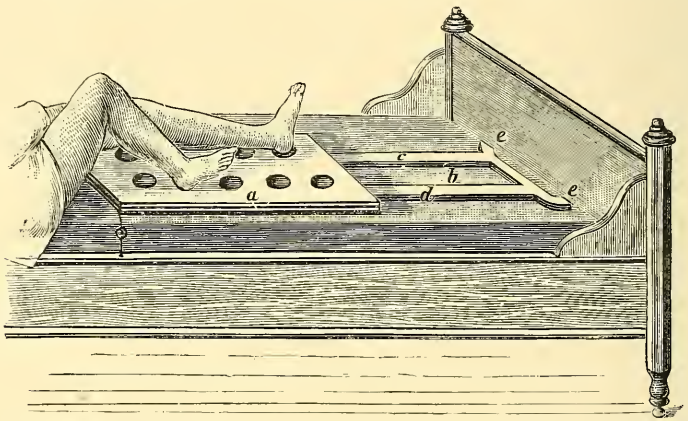

Fig. 86.

back on the bed, making short halts between these movements. At first the bar is fixed at such a height that the leg, when resting upon it, forms an obtuse angle with the thigh ; the distance from the patient should be such that the leg need not be unduly flexed. The bar must not be touched by the leg until the heel is brought to rest on it. The nearer to the body of the patient the bar is fixed, the more difficult will it be for the patient to avoid knocking against it. The higher the bar is fixed, the more difficult will it be for the patient to carry out this exercise. The following modifications will be found useful :

(*a*) Height of the cross-bar from the bed, 15 inches; proximal distance from the ankle, 4 inches. One limb flexed in knee-joint, raised and put on the bar ; short rest there ; return to original position.

(*b*) Height, 20 inches; same distance from ankle; same exercise as at (*a*).

(*c*) Height, 15 inches; proximal distance from ankle, 8 inches; same exercise as at (*a*).

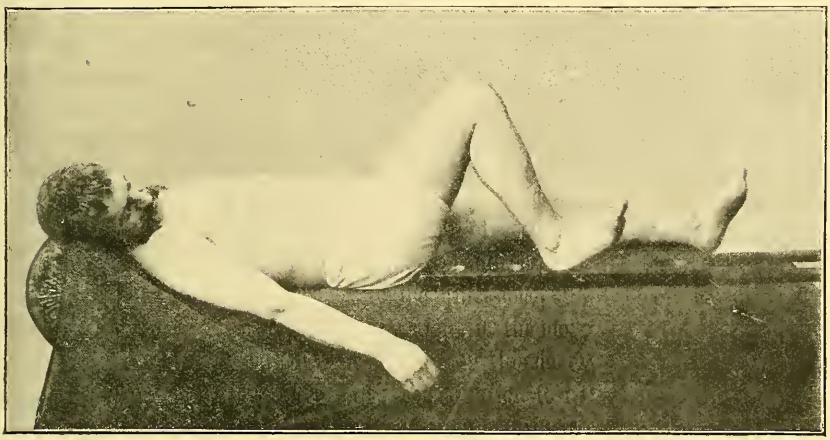

Fig. 87.

(*d*) Height, 15 inches; bar fixed just over the knees; same exercise as at (*a*).

(*e*) Height, 20 inches; bar fixed halfway between knee and ankle;

Fig. 88.

the exercise is made such that while one leg is leaving the bar the other is put on it.

(*f*) Both limbs make the movements simultaneously.

91. The apparatus which is necessary for this exercise (Fig. 86)

consists of a board 2 feet long by 1 foot wide, which can be made to slide on a special extension frame. The piece marked *e* in the illustration is covered with felt. The board has two rows of elliptic concavities, with a larger diameter of 4 inches. The apparatus is laid on the bed, so that the felt-covered piece (*e*) rests against the foot-piece of the bed, and the board is then moved towards the patient until its proximal edge reaches the trochanteric region (Fig. 87).

The nature of the exercise may be gathered without difficulty from Fig. 87. At first only one limb at a time is exercised, the heel being put into successive holes, both upwards and downwards. The following modifications will be found useful:

(*a*) The heel takes one hole after the other.

(*b*) The heel misses every other hole.

(*c*) The heel is put into the various holes at the command of the medical man.

(*d*) Both limbs practise simultaneously, taking hole after hole.

(*e*) One heel is put into the lowest, the other into the uppermost, hole; while the one moves up the other moves down.

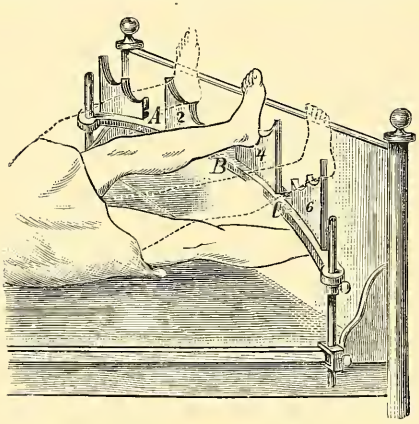

Fig. 89.

92. Instead of a single cross-bar, a more complicated apparatus is used, the arrangement of which will be seen from the accompanying woodcut (Fig. 89). The board *a* supporting the foot-rests is concave, with its concavity looking towards the patient; the foot-rests bear two notches which are large enough to receive the heels, even if covered with socks and boots. The foot-rests are 8 inches high, 6 inches wide, and 4 inches distant from each other. The practice consists in putting the heel either into the spaces between the foot rests (marked A, B, C), or into one of the notches (marked 1-8). The following modifications will be found useful:

(*a*) The heel of the exercising limb is put in succession into the spaces A, B, C, returning each time to its original position.

(*b*) The heel is put into the spaces A, B, C, and conversely.

(*c*) The heel is put into the notches marked 2, 4, 6, 8, returning to the original position from each notch.

(*d*) As in exercise (*c*), but without taking a rest after each notch.

(*e*) As in exercises (*c*) and (*d*), but this time using the notches numbered 1, 3, 5, 7. (The numbers do not appear in the woodcut, but refer to the lower notches.)

(*f*) The heel is taken from notch 1 to notch 2, from 3 to 4, from 5 to 6, from 7 to 8, either resting on the board, on the bed, or on the foot-rests.

93. To the side of a couch (Fig. 90) an apparatus is fixed, the arrangement of which may be seen from the accompanying illustration. At the places marked *a*, *b*, *c*, ball-joints are placed, which

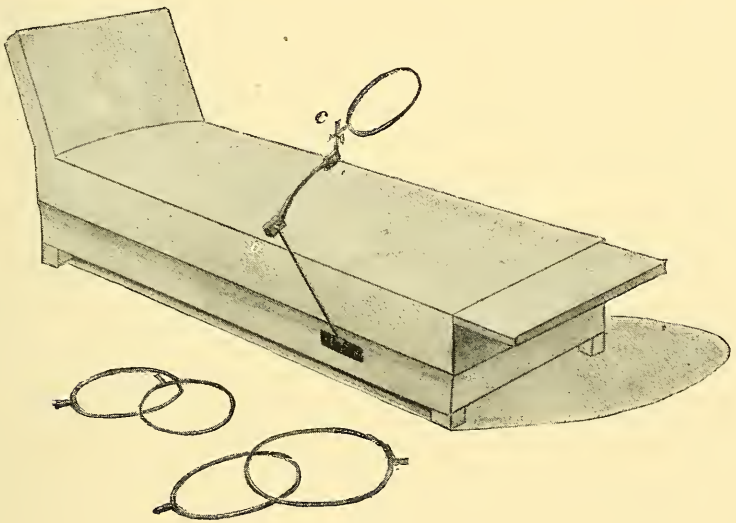

Fig. 90.

can be steadied by means of screws; the upper end beyond *c* is designed to receive the straight attachment of a ring. The apparatus and the hoops are made of iron; the diameter of the hoops varies from 10 to 24 inches. The apparatus may be used in the following manner: The patient lies on the couch, and with his foot in plantar flexion, and the *toes slightly resting on the ring*, he follows the circumference of the ring. The ball-joints allow of a multitude of positions. This exercise is easier with larger rings, but it is generally rather difficult, and therefore only indicated in cases of slight ataxia.

94. The illustration represents the patient as if seen from above lying on the couch. Two wooden rings are required, of a diameter of about 10 inches, with handles fixed to them. The rings are either

held by the attendant or—in suitable cases—by the patient himself. The patient has to put either one or both legs through the ring without touching it; or he may use two rings, one for each limb, and practise the movement, either alternately or simultaneously, with both legs.

Remarks on Exercises 89 to 94.

89. The wooden disc replaces the finger of the doctor. It further furnishes, from its size, a good resting-point for the heel, and may with great advantage be fixed to any part of the limb for the practice of static coordination. When the patient practises with closed eyes, the wooden disc produces a tactile impression strong enough to serve as a substitute for the lost cutaneous sensibility.

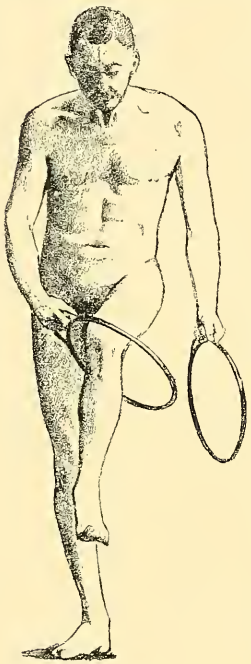

Fig. 91

92. The movement from 1 to 2, 3 to 4, etc., is more difficult than that from 1 to 3 or 2 to 4, etc. For practising with bare feet, the edge of the notches should be rounded off or padded. The combination of strong muscular contractions (lifting the whole limb) with fine coordination movements requires great care and attention on the part of the patient and doctor.

93. This apparatus should only be used in conditions of pseudo-paralysis of the peronei, and then only in the preataxic stage. When using these appliances the medical man should not forget that the most tiring of all movements is raising the lower limb with the knee extended; such movements, therefore, should be made as seldom and for as short a time as possible. As soon as the patient has become proficient on the apparatus its use should be discontinued, and exercises out of bed substituted which do not require the use of apparatus, but at the same time fulfil the same purpose. The reason for this change of exercises is to be found in the tendency of the patients to practise exercises on apparatus which they have already learnt in a negligent fashion. Patients who have to interrupt the treatment and return home may well be given one or two of the above-described apparatus for home practice.

Exercises for the Recumbent Position, to be practised with Closed Eyes.

The ideal which we should endeavour to realize is that every patient should learn without control of the eyes to carry out those movements which a healthy person would be able to perform with his eyes closed, but no others. Most of the apparatus which are commonly used for the movement treatment of tabes require, even in perfectly normal people, the constant control of the movements by the eyes. They are therefore quite unsuitable for exercises that have to be performed by tabetic patients, in whom the optic sense only partially replaces the lost sensibility of the skin, joints, and muscles. The tabetic has with his eyes, not only, like a healthy person, to judge the external conditions under which his movements take place, the nature of the ground on which he is standing, its resistance, the extent of the movement, and so on, but he has also to have recourse to his eyes for any information that he requires regarding the position of his limbs at any given moment while the movement is in progress, or about the distance which has already been, or still has to be, traversed—in short, regarding all those components of a movement, a knowledge of which a healthy person derives from a multitude of sensory impressions. If control by the eyes is absent, the behaviour of the patients varies according to the degree and the kind of sensory disturbance that may be present.

In a case of *slight loss of sensation*, when the muscular sensibility is still able somewhat to compensate the loss of articular sensibility, movements which with open eyes are executed quite correctly assume a peculiar spasmodic type: the contraction of the muscles becomes greater than is necessary in order to overcome the weight of the limb which has to be moved, but the main character of the movement will not essentially be altered. Such cases are met with only in the preataxic and the early ataxic stages. Movements which from their very nature require a larger amount of muscular work should almost entirely be excluded from the daily programme of the patients, and permitted only when the loss of sensibility is slight.

In cases of *moderate severity* the movements become more rapid as soon as the eyes are shut; exercises which the patient had already learnt to perform slowly and evenly become again jerky and interrupted; this characteristic becomes more marked when the eyes are closed.

In *severe cases* the patients are either totally unable to keep the flexed lower limb in a certain prescribed position, or can only do so with great difficulty.

In *very severe cases* of loss of sensibility, but which yet widely differ from those most grave cases that have become completely anæsthetic, the patients are very uncertain in the choice of the muscles which they want to contract, and commit many errors of innervation. Thus, a patient may raise his leg while he really wishes to flex it, or extends it instead of raising it, and so on. Very characteristic of this stage is their uncertainty—or, rather, ignorance—as to the moment when a movement has been completed; for instance, the limb is already extended and rests on the bed, while there continue spastic contractions of the quadriceps cruris muscle; or, when the Exercises 1-16 are to be made, during which the heel should slide up and down on the bed or couch, the patients flex the thigh to such a degree that the heel is raised high from the bed, and even the leg is raised owing to the concomitant innervation of the quadriceps. If such a patient is prevented from executing the intended movement by holding his leg down upon the bed, and he has a sufficient amount of cutaneous sensation left, it is easy to produce in him an illusion of a movement taking place which in reality has not been made at all.

Practice brings about an improvement even in these cases. The amount of possible improvement depends on the degree of sensibility to movements that was present at the beginning of the exercises; the amount of improvement actually achieved depends on the length of the treatment, and last, but not least, on the skill and ability of the medical man supervising it. *Slight and moderately severe cases* may improve to such a degree that they become able to perform all movements equally well, whether they follow them with their eyes or not. *Severe cases* usually continue for a year or longer to shew a marked difference in their movements as regards both kinds of exercises; nevertheless they shew constant, though slow, improvement. Such patients always control their movements with their eyes. When they move about in the dark, they naturally perform their movements with much less precision than when they can regulate their movements with their eyes; but even so their movements shew an enormous improvement in comparison to what they were before the treatment.

One of the movements which is made without control by the eyes, although the patient has his eyes open, is flexion of the leg while the patient is lying on his stomach. As only one group of muscles is called into play, it would be an admirable exercise were it not that there arise two difficulties in connection with it: First, the necessity of counterbalancing the whole weight of the leg, and, secondly, the

important fact that *pure flexion of the leg is hardly ever performed in ordinary life*. The first-mentioned difficulty becomes very obvious when patients with a considerable amount of loss of sensibility lower the flexed leg on the bed again (extension by means of contraction of the flexors), a movement which throughout demands an accurate adaptation of the muscular contraction to the weight of the leg. We see therefore regularly, even in moderately severe cases, that the leg suddenly drops on the bed. This movement becomes still more difficult if carried out with both legs, and is even in slight cases often impossible, on account of the large amount of accurate coordination it requires. It is therefore well adapted to serve as a means of detecting slight loss of coordination, as well as differences of coordination between both legs. The movement is difficult, and apt to unduly tire the patient.

When should the movements be practised with exclusion of the control of the eyes? From the beginning; for a knowledge of how the patient performs his movements when unaided by his eyes is absolutely indispensable for making a prognosis. A more extensive use of this diagnostic factor should be made as soon as the patient has learnt somewhat to keep his movements under control. In slighter cases a fortnight will suffice; in others it may be six months before the patients can be allowed to practise with their eyes shut. This modification of the exercises should be introduced very gradually, in order to avoid undue fatigue on the part of the patient. It may be found expedient to introduce, as an intermediate stage, exercises during which the patient has his eyes open, but instead of keeping them fixed on the movements of his limbs, he looks at objects further away, such as pictures on the wall opposite, or he is told to look out of the window, and so on.

A separate group of exercises which likewise belongs to those during which the control of the movements by the eyes is excluded, may be called *sensory exercises;* that is, the patient imitates from memory with his other limb the positions which the first limb has occupied or is still occupying. For instance, the patient is lying on his back, the limb (*a*) is passively flexed in the knee-joint until a certain angle is formed, and then held in this position; the patient, who has been attentively following the movement with his eyes, is now told to shut them, and to bring his leg (*b*) into the same position as that occupied by the limb (*a*). This movement being completed, the patient opens his eyes and corrects the mistake that may possibly have been made; or the patient himself brings his limb (*a*) into the

position indicated to him, and keeps it there while he completes the exercise as before.

Remarks.

(*a*) These exercises require a not inconsiderable degree of sensibility to movements, and are therefore most suitable in cases of moderate severity; they provide also an excellent means for studying the existing differences regarding the acuity of the motor sensibility in both legs.

(*b*) Passive movements are much more difficult for the patient to imitate than active movements.

(*c*) Obtuse angles are more difficult to imitate than acute ones.

(*d*) The exercises are difficult and tiring; only those movements should be practised that do not require a large amount of muscular force, and are likely to unduly strain the attention of the patient; movements that can only be made without support of the leg should be avoided.

(*e*) For the purpose of comparison, and in order to obtain a means of marking progress, daily records of the exercises should be kept.

B. Exercises in Sitting Posture.

We generally prefer tabetic patients to practise movements in a recumbent position—first, because normally very few movements are possible in a sitting posture, and, secondly, because the recumbent position allows more freedom and a greater variety of movements.

In cases of severe loss of coordination, when the patients have for years been unable to stand, and have lost the ability of making even the simplest coordinate movements, we let the patients practise movements in the sitting posture, as well as lying down; the patients should be fully dressed for these exercises, and wear stout, heavy boots. The movements are, of course, very simple ones, such as raising the thigh with the knee flexed and putting the foot on the ground firmly. For some time the patients will not succeed in putting the foot down in such a manner that it touches the ground with the entire sole. It is sufficient if the patients become able to cover with the foot the traced footprints on the floor; to induce them to try to do more at this stage of the treatment is very risky; the patients soon become tired and very excited. Care should be taken that the ankle does not turn over, and that the contact with the floor is not too violent. On the first occasion the leg should be directed by the medical man who supervises the exercises. The patient should

practise no more than four series of exercises, each series consisting of four movements, and practise with one limb while the other is resting. It is not advisable to let the patient practise with both limbs together; that combination does not occur in ordinary life, has very little importance from the standpoint of coordination, and requires a large amount of muscular strength.

If one watches people in an advanced state of tabes while they are sitting, one notices a characteristic position of the lower extremities which alone enables one to make a diagnosis; viz., the limbs are flexed in the knee-joints and abducted to such a degree that both knees drop outwards and the outer edge of the feet rests on the ground. The cause of this anomalous position of the lower limbs is to be found in a diminution of tone of the adductor muscles, in consequence of which the lower limbs become unable to resist the influence of their own weight, which acts in the direction of abduction. We have seen the same take place in the recumbent position. For this reason the patients should be instructed to make movements of adduction between the other movements, and when sitting to keep their limbs in a normal position.

The greatest practical importance, however, is attached to the practice of such important movements as *sitting down* and *getting up*. More often than not the patients have almost lost the power of getting up from a chair or of sitting down. These two movements should be practised in the following manner: After the completion of an exercise which he has performed standing, the patient is taught how to resume his seat and *vice versâ*. It will be necessary to insist on the correct execution of these movements.

Let us watch a tabetic patient, whose tabes is so severe that he cannot get up from a chair, try to rise. He makes futile efforts by moving his body from one position into another; he moves his legs, *but apparently it does not occur to him to make that absolutely necessary initial movement with his legs without which getting up from the chair is impossible—namely, to move his legs back and under his body* in order that his centre of gravity falls somewhere in front of the ankle-joints. The patient has simply forgotten a movement which a healthy subject carries out as a matter of course. We say "forgotten" with a purpose, for *the patient has not lost* the ability of making such a movement; indeed, *he carries it out as soon as he is reminded of the import of it.* The same applies to that other important movement, viz., *bending the body forward.* Once the patient is reminded of these necessary preliminary movements, he usually learns how to get up within a few

minutes. His manner of executing this movement depends on his degree of ataxia; it does not matter whether he completes it already the first time, or leaves part of it undone—whether it costs him great exertion, or he sways a little in doing it—the movement has been learnt as soon as the patient grasps the idea that the essential part of the movement is the transference of the centre of gravity from behind to a place a little in front of the ankle-joints.

When sitting down, the patients simply let themselves fall into the armchair whenever they try to sit down without support or without leaning on the arm-rests. This is the result of the patient neglecting to bend the body sufficiently forward while flexing the knee and hip joints, in consequence of which the weight of the body is transferred back and beyond the heels. The patients should, therefore, be instructed to observe the following rules:

Sitting down.—The knees should be slightly and to the same degree flexed, a matter of some difficulty, both on account of the state of hyperextension in which the knees are usually kept in consequence of the hypotonic condition of the muscles of the calves, and because both knees are hardly ever equally affected, so that the patient has to direct his attention to either of them. After the knees have been flexed, the body has to be slightly bent forward. The patient then begins to sit down, flexing his knees still further while the bending forward of the trunk continues. Thus the line of gravity remains in the neighbourhood of the ankle-joints, and the body, maintaining its balance, is slowly lowered into the chair. The body should be kept in the anteflexed position until the patient is actually sitting in the chair. Care should be taken that the patient's ankles do not turn over or he himself pitch forward.

Getting up.—Both feet should be drawn back until their heels are partly under the chair. The body is then bent forward until the knee-joints have completed a movement of partial extension, when it is slowly erected. It should not be forgotten that a healthy person when sitting far back in a low chair draws his feet as much as possible under the chair, and when getting up balances himself on the balls of the toes, and not on the whole foot. Thereby the centre of gravity is at once transferred far enough back, so that it does not become necessary to bend the body much forward. On the other hand the tabetic patient cannot balance himself on the toes; he needs the whole foot, and especially the heel. He can, therefore, draw his feet only so far back that it is still possible for him to put his heels on the ground; that is, the heels are put just beneath the edge of the seat of

the chair. Consequently the body must be bent forward so far that its centre of gravity is poised above the heels. When the patient is sitting far back in the chair, it often happens that even a maximum degree of anteflexion of the body is not able to shift the centre of gravity sufficiently forward, and the patient cannot rise on his feet. It is therefore necessary for the patient not to sit too far back in the chair, if he wishes to try to get up from it without support.

C. Exercises in Erect Posture.

Walking Forward.

The first lessons should be devoted to the practice of the various forms of walking and the position of the upper extremities.

Exercises.

1. Walking slowly forward. The patient has to traverse a distance of about 20 yards, walking very slowly and paying his fullest attention to the manner in which he moves his legs.

2. The patient has to correct the exaggerated outward rotation of his legs. The angle enclosed between the two feet should not be more than 90 degrees.

3. The same; but the patient has to adduct his lower limbs so much that the distance between the heels is no more than 6 inches.

4. Walking slowly, the patient keeps his feet almost parallel, the heels are brought together after each step; the walking basis has a width of 6 inches.

5. The same as 4, but the patient is now directed to make steps of medium length (about 13 inches).

6. The same as 4; each step is only 9 inches long.

7. The same as 4; the length of each step is 24 inches.

Remarks on Exercises 1 to 7.

(*a*) The patients practise individually; their attention must be assiduously drawn to every detail of the movement which is to be executed.

(*b*) The patients should wear a light dress without a coat; the ladies should wear knickerbockers, to enable them to watch the movements of their legs. All patients should wear high lace-up boots, which give a great deal of support about the ankle, with low and broad heels.

(*c*) At first short distances only (3 to 5 yards) should be traversed by the patients.

(*d*) The tabetic patients have *a tendency of walking too quickly*; they should be enjoined as much as possible to walk slowly.

(*e*) After each exercise the patient's pulse should be controlled; at the beginning of the treatment the pulse-rate rises quickly to 120 or 150 beats; no fresh exercise should be begun before the pulse-rate has become normal again.

(*f*) At the slightest sign of fatigue the patient should sit down and rest; for this reason numerous chairs should be provided along the walls of the exercise-room.

(*g*) The patients should be instructed, before beginning to practise walking, that they have to transfer their weight upon one leg, in order to free the other for the purpose of swinging it forward, and that they should bend the body forward.

(*h*) Fig. 66, Pattern I., shews the broad black stripe on which the patients should walk during these exercises.

(*i*) Walking-sticks should be used by the patients at these exercises.

(*j*) The patients should keep their eyes fixed on their feet in walking.

The following exercises are suitable for the practice of steps of certain length, for which Fig. 66, Pattern III., should be used. We recommend three different steps:

1. The *long step*, which is easy for a man of medium height, but very difficult for tabetic patients; it should, therefore, be reserved for patients who have already made good progress. This step is 28 inches long.

2. The *half-step* is 14 inches long; this is the length which is easiest for tabetic patients.

3. The *quarter-step* (7 inches long).

Exercises 8 to 18.

8. Half-steps forward—single steps (that is, after each step the feet are placed in apposition).

9. Half-steps forward—progression.

10. Three-quarter-steps forward—single steps.

11. Three-quarter-steps forward—progression.

12. Quarter-steps forward—single steps.

13. Quarter-steps forward—progression.

14. Half-step forward (single step); quarter-step forward (single step). This combination of two steps of unequal length is to be repeated five to ten times in succession.

15. Three-quarter-step forward (single step); quarter-step forward (single step). Repeat five to ten times.

16. Half-step forward with leg (*a*); three-quarter step with leg (*b*); quarter-step with leg (*a*); half-step with leg (*b*); three-quarter step with leg (*a*); quarter-step with leg (*b*). Repeat three to ten times.

In this exercise each leg has done the same amount of work (three steps), but always changing the length of the steps and returning to the initial position after completion of the third step.

17. Quarter-step forward with leg (*a*); quarter-step with leg (*b*); quarter-step with leg (*b*); quarter step with leg (*a*).

18. Three one-quarter steps forward with leg (*a*); two one-quarter-steps with leg (*b*); half-step with leg (*a*); three-quarter-step with leg (*b*).

Remarks on Exercises 8 to 18.

(*a*) In these exercises are *exactly* determined the position of the lower extremities and of the feet, the width of the walking base, the length of the steps; the *tempo* of the steps is left to discretion.

(*b*) "Single step" means that both legs step out the same distance, so that after completion of both movements they are again in the "initial" position. "Progression" means, in analogy with ordinary walking, that the second leg, passing the first, swings forward, thus traversing double the distance prescribed by the first leg; then the first leg does the same, and so on.

(*c*) "Initial position" means both feet in apposition; each of the exercises 14 to 18 ends with the feet in "initial position."

(*d*) At each exercise the "commencing" leg is the one which did *not* begin the immediately preceding exercise; both legs perform an equal amount of work during each exercise.

(*e*) Fig. 67 explains the exercises 14 to 18; (*a*) and (*b*) mean right and left leg respectively; the numerals indicate the sequence of the movements; the distance from one division to the other is equal to one-quarter-step.

(*f*) It is not difficult to vary the above described exercises, but in doing so one should remember, first, that long steps require careful supervision; and, secondly, that the patients should not be made to stand long on one leg.

Walking Sideways.

Exercises.

19. The patient makes a half-step to the left, then returns to his original position (Fig. 92).

Fig. 93.

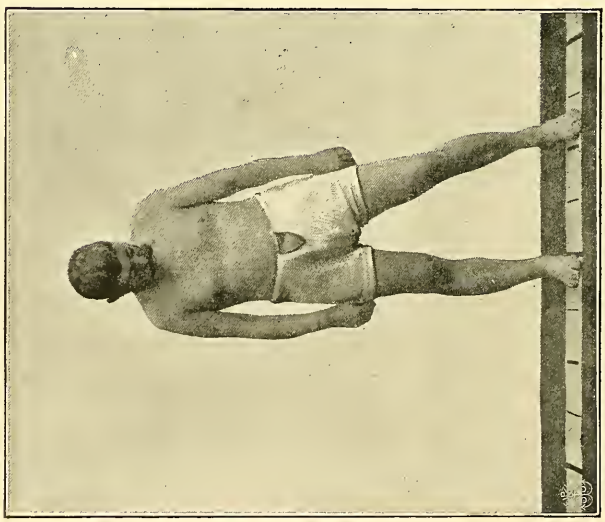

Fig. 92.

20. Three-quarter-step to the right, one long step to the left, then a short step back to the original position (Fig. 93).

21. Several quarter-steps to the left, then return to original position and *vice versâ*.

22. Longer and shorter steps to be made indiscriminately in either direction.

Remarks on Exercises 19 to 22.

(*a*) Walking sideways is easier than walking forward. Hence advanced cases of tabes ought to begin with practising lateral progression; but slight cases and cases of moderate severity may practise walking sideways in the intervals between the various exercises bearing upon forward progression, practising making long steps forward only after lateral steps of the same length have been already practised.

(*b*) Figs. 46 to 52 demonstrate clearly the mode of progression in walking sideways.

(*c*) Under normal conditions, when persons make a long step to the right or left, the leg that is to make the step tries first to establish a hold on the ground by extending the foot so that the toes touch the ground before the heel, which is not lowered until the other (or supporting) limb has been pulled after. Tabetic patients, on the other hand, avoid balancing themselves on the toes, on account of the looseness of their ankle-joints, and they should not be persuaded during the earlier part of the treatment to try to balance themselves on the toes. It is further necessary to keep the steps below their normal length, in order to enable the outstretched limb to rest on the whole foot while the other follows after.

(*d*) During the first lessons in walking sideways no notice need be taken of the tendency of the patients of making steps of unequal length.

Walking Backward.

In this mode of locomotion, as in walking forward, the body bends slightly forward. Walking backward, however, further necessitates pulling the body back while the previously supporting limb is pulled after the one that has just stepped back; it consequently requires greater efforts at coordination, and is very trying and tiring to tabetic patients. This difficulty grows in direct proportion to the length of the step required, and is felt more keenly than in walking forward. For this reason short steps should be the rule.

Exercises.

23. One-quarter-step backward; single step.

24. One-eighth-step backward; single step.

25. One-eighth-step backward; continuing.

26. One-eighth-step backward, the left foot stepping out first; then two more such steps with the right foot leading.

27. One-quarter-step backward; continuing.

28. One-half-step backward; single steps.

THE CONTROL OF THE MOVEMENTS BY THE EYES.

Tabetic patients should always follow their movements with their eyes. We have already mentioned that ataxic movements become still more ataxic when they are carried out with closed eyes, and that movements which are usually made in a regular manner become at once ataxic when the patient no longer controls them with his eyes. The reason for this interesting phenomenon is to be found in the increased importance of the sense of sight for the orientation of the body and its extremities, once the sensibility of the skin, muscles, joints, and bones, has become partially or entirely lost. In studying a new exercise the patient should closely follow with his eyes every phase of the movements he is practising. When the details of the new movement have been thoroughly mastered, the patient should begin to practise the same movement with his eyes shut. Although he will not immediately succeed in this task, much will already have been gained if the patient becomes proficient enough to be able to perform his movements without constantly having to keep his eyes fixed on his arms or legs.

1. At first we ask the patient, when practising, not to look at his feet, but on the ground about 1 to 2 yards in front of them. He then repeats all the movements which he has already acquired, beginning with the easiest. It will be interesting to see how at once the former mistakes reappear—namely, the tendency of walking quickly, stamping with the feet, the outward rotation of the legs, and so on. The steps become again irregular in length, but this is a matter of minor consideration so long as the patient is able to keep on the black stripe when walking. In this manner the patient practises walking forward, sideways, and backward. Great care should be taken that no accident happens; sprained ankle, *e.g.*, is, unfortunately, one of the most frequent mishaps to tabetic patients unless they are most carefully guarded against any such untoward event. Short, medium, and long steps should be practised until the patient has become quite proficient.

2. Next the patient has to keep his eyes fixed on a certain point on

the wall opposite him—*i.e.*, about 20 to 24 yards away from him. This modification increases considerably the difficulties which the patient will have to overcome; his incoordination will immediately become worse, and he will be quite unable to keep on the black stripe while walking. The patient has to go through the same exercises as mentioned in the previous paragraph.

3. The patient is told to practise with his eyes fixed on a point on the opposite wall, close to the edge of the ceiling.

4. A point on the ceiling, situated almost immediately above the patient, is to be kept in view by the patient while practising.

5. The patient has to keep his eyes closed while practising walking forward, sideways, and backward.

i. Beyond the duty of careful supervision, the medical man should not neglect to interrupt the exercise at once if he finds in the pulse of the patient symptoms of fatigue.

ii. No patient should be required to walk backward with his eyes closed before he has mastered walking forward and sideways.

iii. and iv. These exercises demand a certain amount of dorso-flexion of the head and neck, whereby the equilibrium of the body is materially disturbed, sometimes so much so that the patient can scarcely keep on his legs. Instead of shutting the eyes, the same purpose would be achieved if the patient's legs and feet were hidden from his view. Ladies should, therefore, after a time be permitted to wear their skirts again; whereas the men, at this stage, should practise with their overcoats on, or should wear long mantles or aprons. This mode of practising is most important, for it as nearly as possible approaches to conditions which exist in ordinary life. The exercises gain additional value when the patients are able to practise in groups, for then they have to look out in order to avoid collisions with one another or with obstacles placed in their way.

THE TEMPO OF THE MOVEMENTS.

One of the most important tasks in the treatment of tabes is the fight against the tendency of walking quickly which characterizes the tabetic patient. It is interesting to see how patients suffering from paresis do not become able to walk more quickly before their paretic condition generally is improved; while, on the other hand, in tabetic patients the acquisition of a slow gait shews improvement, because here slowness of movement means regular employment of the antagonists—that is, coordination has been regained.

A further step towards a cure is made when the patients learn how to alter at will the tempo of their movements; the accuracy and certainty of locomotion depends to a great extent on the ability of the patient to vary the tempo of his steps as circumstances demand.

If in the beginning of the treatment the patient is requested to walk slowly, one notices, as a rule, that the interval between two consecutive steps becomes longer, but that the step itself is made rapidly. The converse, however, should be the aim—viz., the interval between two steps should be shortened, thus producing regular and uninterrupted progression, but the amplitude of the step should be increased. The intervals between the steps can best be shortened by requiring the patient to march to words of command, or other signs, such as clapping the hands. As soon as the patient has been told the direction in which to walk, the width of the walking base and length of the distance to be traversed, and in what direction he is required to look, the moment for each step is signalled by clapping the hands. It is thus in the power of the medical man to regulate the duration of the intervals between the steps. The patient will be the more able to follow the signal promptly the less marked is his incoordination, or the greater the progress which he has already made.

The object of this exercise is to teach the patient to transfer without delay his centre of gravity on to one leg in order to enable the other leg to step out at once.

The use of a metronome for the purpose of regulating the succession of the steps is not to be recommended, for the metronome, once set, will during each time unit give the same number of signals, which circumstance the patient will at once utilize in this way, that he will make a rapid step and then have a comparatively long interval, during which he can get ready for the next step.

The following precautions should be taken:

1. The medical man should let the patient begin to practise without first fixing the length of each step.

2. The patient should make half-steps only. Long as well as short steps should be avoided; the former are too tiring for the patient, the latter are invariably turned into long steps by the patient's tendency to making brisk movements.

3. Next come medium steps sideways, both with and without prescribed length of the step.

4. Walking backward should not be attempted until towards the end of the treatment, when the patient has become proficient in all other forms of walking and has regained confidence in himself.

5. The patient should control the movements of his limbs with his eyes; walking at command, without the control of the eyes, requires a high degree of coordination which is very rarely achieved by tabetics.

THE CHANGE OF DIRECTION.

Turning Round.

One important factor determining the safety of the movements of the human body is the power of promptly altering the direction in walking; on it depends the possibility of "moving out of the way," without which walking in busy thoroughfares is impossible. A healthy person performs this act by turning on one heel and pulling the other limb after. Tabetic patients have the greatest difficulty in changing their direction in walking; they increase the space between their feet and alter their direction as little as possible. In consequence of their inability to turn on the spot they describe long curves.

The patient should stand with his heels close together, but the toes should be about 8 inches apart. The patient then turns slightly on one heel; he then lifts the other foot off the ground, and puts it down by the side of the first so that the initial position of the feet is resumed. In this manner the whole body describes a limited movement round its vertical axis. At first the angle thus described by the patient should be made as small as possible; its size may be gradually increased, until the patient becomes able to describe an angle of 90 degrees, when the progress may be a little accelerated. Figs. 69 and 70 represent diagrams which should be painted on the floor, and which in the earlier stage of the treatment will be of great help for instructing the patients how to turn round. The exercises should be made (*a*) without, (*b*) with command; (*c*) improved cases may be allowed to wheel round an angle of 180 degrees.

WALKING ZIGZAG.

Fig. 67 represents a zigzag border which is painted on the floor, and on which the patient must walk closely following its course. At first the patient should make two steps along each arm of the zigzag border, but he will soon learn to make steps as long as the arms of the border. Inasmuch as the patient has to turn on both heels if he wants to perform this exercise correctly, walking on the zigzag border will invariably be found more difficult than turning round. The border is 8 inches wide; each arm has a length of 24 inches.

Walking in a circle has been quite abandoned by us, for if the

radius of the circle be short, the patients soon become giddy and tired; and if it be long, the movement possesses not enough value from the point of view of coordination to compensate the patients for the fatigue and strain resulting from such an exercise.

STANDING AND WALKING WITH BENT KNEES.

The importance of walking with slightly bent knees has already been discussed. Nearly all our patients, even those with only a very slight ataxia, have lost this faculty in consequence of the hypotonic condition of the muscles and the hyperextension of the knee in order to prevent the knees from suddenly bending under them. Under proper supervision, walking with slightly bent knees is capital practice; it makes the patient again accustomed to a form of coordinate movement during which the equilibrium of the body is chiefly maintained by the combined action of the flexors and extensors of the knee-joint, and not by the pressure of one articular surface upon the other, as is the case in the stiff gait of the tabetic. Again, flexion of the knee releases the articular cartilages of much pressure; the necessarily increased action of the muscles does not unlikely increase the muscular tone too. Tabetic patients have naturally much difficulty in practising this exercise, for the proper contraction of the antagonists which is necessary for the production of that slight flexion of the knee-joint required for this exercise demands intact muscular sensation. The slightest anomaly of tactile sensation will produce either extreme extension or sudden flexion of the knees. As even slight cases of ataxia shew impaired muscular sensation, there will be few patients who will be able to keep their knees slightly bent for longer than a minute or two. It will be sufficient if the patients can walk with their knees considerably flexed. Duration and repetition of the exercises should not be left for the patients to determine, who in the absence of every sensation of fatigue are apt to overdo it. Another point must be mentioned here which is of the greatest importance. The patients experience great difficulty in simultaneously bending both knees and in keeping them in that position; one invariably finds that one knee is extended while the other is flexed, and so on. The cause of this interesting phenomenon is a double one—first, the unequal amount of loss of sensation that exists in both legs, and, secondly, the loss of the power of simultaneous innervation of several groups of muscles which are situated far apart.

WALKING ON THE NARROW BORDER.

The "narrow" border has a width of 4 inches, which is about the width of the sole of a boot. The practising patient puts first one foot on the border, and the other by its side; he then practises the following exercises:

1. Foot (*a*) on the border, (*b*) by its side; (*b*) is then put in front of (*a*); (*a*) is brought forward to the side of (*b*), and so on.

2. The patient is asked to make steps of a certain length (*cf.* Fig. 66).

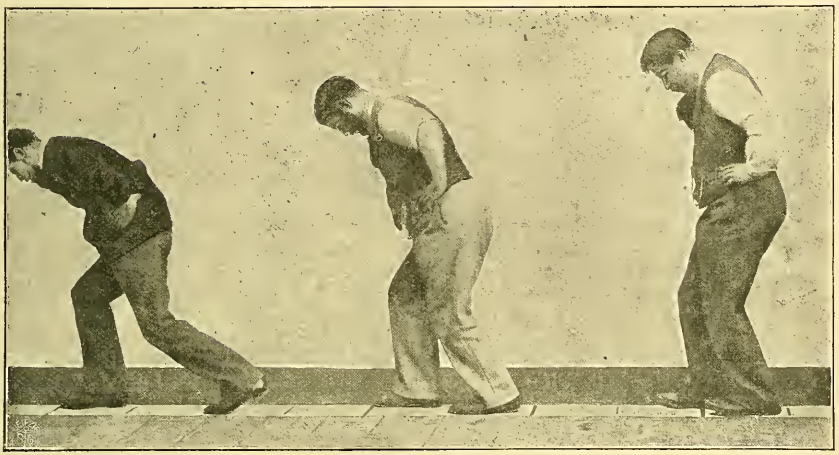

Fig. 94.

3. The patient walks putting one leg in front of the other on the narrow border without stepping off it (Fig. 95).

4. As in 3, but the steps are of a certain length.

These exercises are very difficult; the most difficult of them is Exercise No. 4, for there the walking base is not wider than the sole of the boot, and the weight of the whole body must be balanced on one limb. Further, Exercises 1 and 2 provide for a rest after each step, whereas 3 and 4 demand continued progression without halt or widening of the walking base. The patients walk like healthy persons would do if they had to walk on a narrow board which is fixed a considerable distance above the ground.

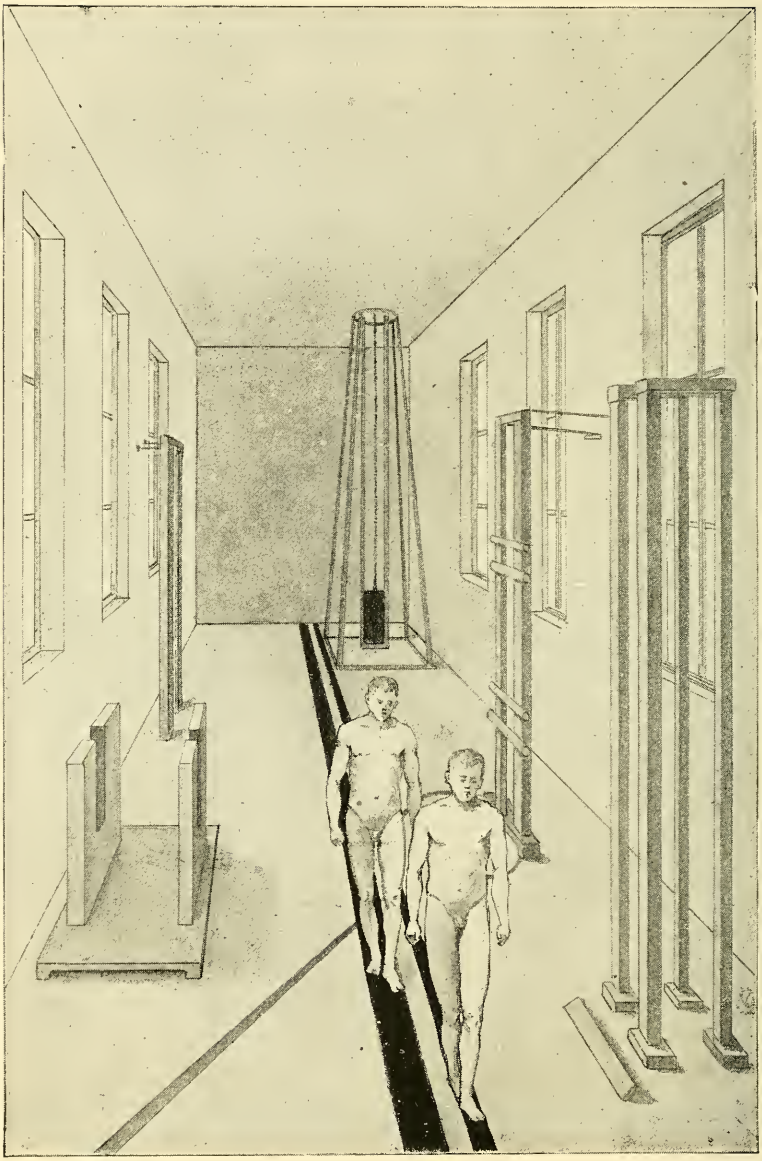

Fig. 95.

THE PRACTICE OF WALKING IN CASES OF SEVERE AND SEVEREST (PARALYTIC) ATAXIA.

With regard to the walking exercises which have up to now been treated, it was presumed that the patient was able, with help, at any rate, to balance his body on his lower limbs—*i.e.*, that he was able to stand. For those patients, however, who have been confined to a bath-chair or the bed, who can only with the greatest difficulty, if at all, support themselves on their legs for a few seconds, special modifications of our system must be designed. It has in many cases of the severest kind been possible to restore the power of walking, and there is not a single case in which it proved impossible to achieve even a slight improvement.

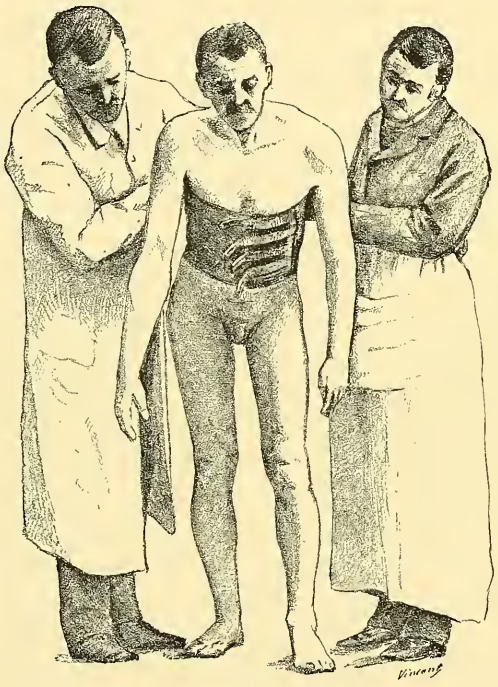

Fig. 96.

Such patients first practise certain movements lying in bed; after a time the patients are brought into a vertical position in order to make them accustomed to this position, and also to the contact of the feet with the ground. This latter part of their exercise is attended by many difficulties, for the knees have a great tendency to bend, the feet turn over, and the body cannot be kept upright. The absolute helplessness of such patients is the more surprising as, while in bed, they are nearly always able to perform certain movements, such as sitting up, turning over on one side, bending the knees, and so on. They have apparently forgotten all those actions and innervations of muscles which play so important a part in keeping the body erect, and one feels inclined to compare the plight of such patients with the con-

dition of a child which in his cot can perform all manner of movements, but yet is unable to stand or walk.

The Belt.—In most severe cases of ataxia it is very difficult to hold the patient in an upright position when he is utterly unable to put his feet down on the ground ; at least two attendants are required to support him. The patient, however, must not be held by the arm or under the arm-pit, for fear of dislocating or breaking the humerus, but he should be held up by means of a broad belt made of double sail-

Fig. 97.

cloth, which is put round the patient's chest (Fig. 96). The belt bears two strong wooden handles on either side, which are placed in the manner shown in Fig. 97. The attendants hold the patient up by means of these handles. The width of this belt, the way in which it is fastened by means of broad leather straps, and the manner in which the handles are attached to the belt, enable the attendants to lift the patient and to hold him up without the slightest inconvenience to the patient. A further advantage is that the patient feels confident that he cannot fall down. A rational and systematic treatment of the most advanced cases of tabes has only been made possible since we have used belts such as we have described.

Supposing a tabetic patient who has entirely lost the power of supporting himself on his legs comes for treatment of his ataxia. The procedure will be as follows: While he is sitting in a chair, the belt is applied; he is then lifted up until he occupies an almost upright position, with his feet resting on the ground. By this means the weight of the body does not entirely rest on the lower limbs. The first lessons will teach the patient to keep his feet on the ground, to put them firmly on the ground and to keep the knees extended. As soon as the patient has learnt to keep his feet and knees steady—and it sometimes takes him weeks to acquire this power—the patient may be induced to try to balance the weight of his body wholly or partially on his lower limbs. Finally the patient may be encouraged to try himself to get up from the chair, while the attendants with their hands on the belt-handles watch him and protect him from accidents.

Walking "on the spot" should be first practised, the patient lifting first one leg, then the other, flexing the limb in the hip and knee joints, then again extending it. It is advisable to instruct the patient to bring his feet down with some force, in order to make him accustomed again to feel the ground under his feet, and to assure him that he is able to put his feet on the ground firmly without danger of spraining his ankle. Actual walking should not be commenced until these fundamental exercises have been tolerably well mastered by the patient. In instructing the patient how to walk, he should first be taught to put one foot in front of the other. Although the support given him by his attendants relieves him of the necessity of balancing his body on the supporting limb, the patient will experience an enormous difficulty in making the simple movement required of him. He will innervate groups of muscles which are utterly unsuitable for the purpose. In a case that came under our observation, the patient, who had not even the worst degree of ataxia, for he could stand for a few minutes at a time, thrust his legs sideward and backward, but never forward, when he attempted to walk; he had not walked for fifteen years. Little by little the patient learns to innervate the necessary groups of muscles and to commence walking.

As soon as the patients have learnt to innervate the muscles which are required for locomotion in a certain intended direction, they have passed from the "pseudo-paralytic" into the "ataxic" stage. The ataxia, which in these cases again is of the severest character, is to be treated on the same principles, using the belt until the patient is able to dispense with it.

This is best done by gradually allowing the patient to support him-

self on his legs, while the attendants simply walk by his side ready to render support the moment it is required. At this stage the patient may be encouraged to use walking-sticks, but it should be remembered that the patient when walking by the help of sticks is apt to transfer his weight further forward than he would do if he were not leaning on his sticks. The rule, therefore, should always be to *let the patient practise without sticks or crutches* as soon as possible, and to allow the use of sticks only as a temporary measure. When the patient has made such progress that he can walk with the help of sticks, the

Fig. 98.

services of one attendant may be dispensed with, and the patient should from time to time, without his knowledge, be allowed to walk unsupported, by the attendant behind him gently releasing his hold on the handles of the belt.

Even less severely ataxic patients, who are of an apprehensive mind or whose confidence in themselves has been shattered by repeated accidents, may be allowed for a time to wear the belt as an encouragement, but care should be taken that they practise without the belt as soon as is possible.

APPARATUS FOR THE PRACTICE OF WALKING.

The apparatus which we commonly use for practising the walking movement (Fig. 71) consists of a cross made of planed deal boards, on which are painted certain outlines and numbers. The patient is asked to stand on the board so that the points of his boots touch the outlines marked **1**. He will then, either voluntarily or at command, put one foot sideward or forward or backward, on one of the marks numbered 2, 3, 4, as required. At first the marks should be

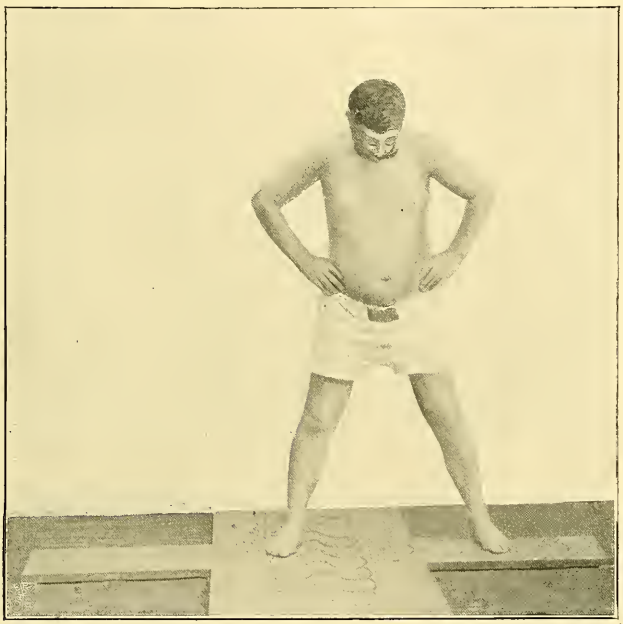

Fig. 99.

taken in consecutive order; later on one or two may be left out, thus making the patient make half or full steps. Figs. 98, 99, and 100 give a good idea of the possible variations. A handrail is fixed in those places where the patient has to turn, and against which he may support himself in case of necessity; but ordinarily the patient should practise on the floor-cross without support.

In connection with the use of the floor-cross, attention should be paid to the following points:

1. The arrangements of the outline indicate not only the length of the steps, but also the position of the feet, much more definitely than is the case with other apparatus.

2. The repeated stepping movement—either backward or forward or sideway—obliges the patient to balance himself on one leg for a considerable time, an action which is very tiresome to him.

3. Figs. 98, 99, 100 represent the normal position of the body during these exercises. It should not be forgotten that it is impossible for the patient, and therefore would be a grievous mistake, to try to compel the patient, to assume anything approaching the normal position of the body.

4. Longer steps backward are possible only in slight cases.

Fig. 100.

The practice on the floor-cross requires the maintenance of the equilibrium of the body, the ability of moving the limbs at will, and a certain amount of staying power. It is, therefore, eminently suited for cases which only lack precision—that is, the preataxic stage, beginning ataxia, and at the end of a course of treatment.

The more important movements that should be practised on the floor-cross are the following:

The initial position consists of both feet placed parallel on the cross with the toes touching the outlines.

1. Left leg forward on 2, then back to 1; right leg to 2, back to 1. (Fig 98.)

2. Left leg to 3, back to 1; right leg to 3, back to 1; likewise with either leg to 4 and 5.

3. Left leg to 2, then to 3, 4, or even 5, back to 1; the same with the right leg.

4. Left leg to 2, then to 4, then back to 1; the same with the right leg.

5. Left leg to 5, then to 4, then 3, then 2, then 1; the right leg the same.

The same set of exercises should be practised with regard to the lateral and backward movements.

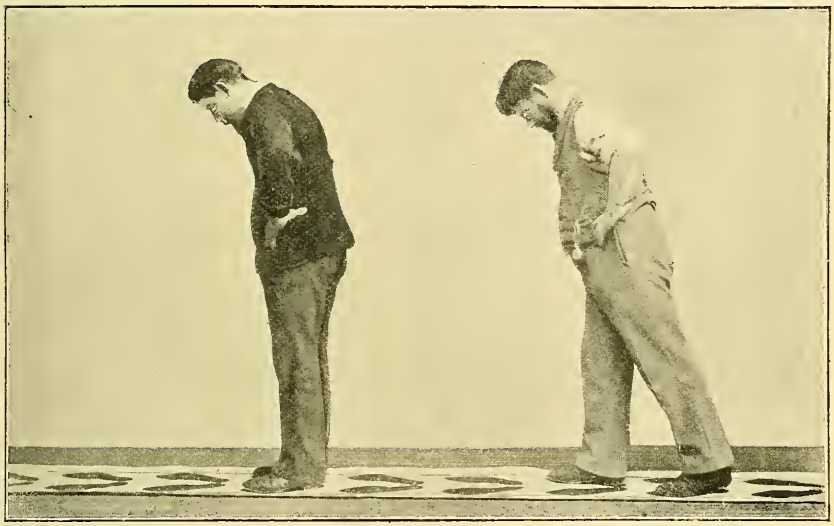

Fig. 101.

Remarks.

The outlines are $4\frac{1}{2}$ inches apart, so that five outlines give the exact length of a full step—viz., 22 to 24 inches.

In practising walking backward, the patient should not step further back than the distance of two intervals (9 inches).

The words of command are: "Left forward three," "right sideways one," and so on.

The Footprints, which are painted on a strip of linoleum or some other stiff material, are intended both for the forward and backward movements. Figs. 68, 101, and 102 give a good idea of their shape, size, and arrangement.

The Stairs.—Walking up or down stairs is such a common and

indispensable movement that it must under all circumstances be practised by the patients, even if their condition forbids practice of other movements of the same difficulty. What makes mounting or coming down stairs so difficult for tabetic patients is the necessity of balancing the weight of the body on one leg while the other is being raised, flexed in the knee-joint, and brought forward in order to make the next step above or below, as the case may be, after which this leg has to receive and support the whole weight of the body while the other is lifted up, and so on. This movement requires a large amount of muscular force and precise coordination on the part of the patient, and much patience and a great deal of supervision on that of the medical man. Heavy patients should not be allowed to practise this movement without at first holding on to the handrails; later they may be permitted to hold on to one rail only, and to use a stick for the other hand. In slight cases, and by patients of light weight, this movement may be practised without the support of handrails or a walking-stick; but the patients must be well instructed in the static principles of the movements, and should practise every detail of the movement with the utmost care and precision. Even then they should be reminded of the necessity of using the handrail whenever possible when walking downstairs alone or after darkness has set in. Fig. 63 shews the arrangement of the apparatus for practising this movement; the steps are 30 inches long, and the handrails are conveniently high; the steps are low, and wide enough to allow of

Fig. 102.

the whole foot being placed on them. The rails are detachable. The pulse should be examined before and during the practice. In cases of pronounced hypotonia of the knees great care is necessary in order to avoid accidents. The patients should practise outside their ordinary exercise hours, after they have had sufficient time for rest.

It is necessary that the patients should learn to carry more or less heavy and bulky objects in their hands, or balance them on their heads, during their walking lessons. Even in the slightest degree of ataxia the patients are much inconvenienced if they have to carry such a light object as a walking-stick, because part of their attention has to be bestowed upon watching the erratic movements of the stick, which, of course, makes them unable to control the movements of their lower limbs. Heavier, and especially bulkier, objects, if carried in one hand only, displace the centre of gravity of the patient to such an extent that walking becomes almost, if not quite, impossible. To be able to carry parcels, etc., in one or both hands is of such importance to the tabetic patient that special practice in the indicated direction is generally welcomed by the patients. Such lessons should be given towards the end of the course of treatment, because they require a large amount of balancing-power on the part of the patient. Weights with handles, weighing from 2 to 14 pounds, parcels of various sizes and weights, long staffs, boards, and so on, are more or less convenient objects to carry. Fig. 103 represents a tabetic patient carrying a bundle and a lath in his hands, and a wicker basket on his head. This wicker basket has a plush skull-cap attached to it which fits loosely on the head; the object of this contrivance is to teach the patient to hold his head steady when walking or turning round, for the basket will fall off his head at the slightest jerky movement he makes. With a little care an almost endless variety of subjects can devised for these exercises.

Fig. 103.

PRACTISING IN GROUPS.

When a patient has become efficient in all the exercises which he has been taught, he may be allowed to practise together with three or more fellow-patients, who should, of course, all have the same degree of ataxia. The patient will thus be taught to move in the presence of, and to come into contact with, a number of people such as he will most probably meet in the street when out for a walk.

Not less than three patients form a group, and practise the following movements:

1. Half-steps forward without command.
2. The same with command.

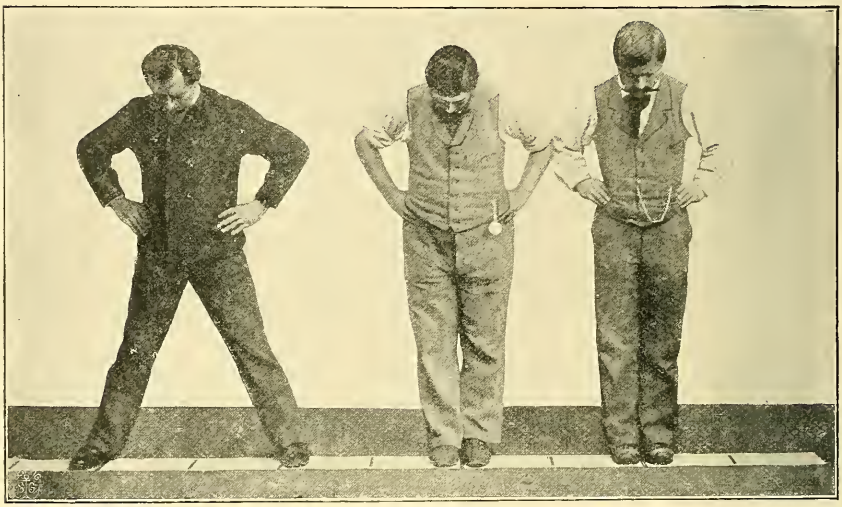

Fig. 104.

3. Standing in single file; distance one half-step; walking with half-steps, all stepping out with the same leg.
4. The same, making full steps instead of half-steps.
5. The same as 4, but the steps are made at command.
6. Exercises 1 to 5 are made with the arms raised above the head.
7. The patients stand the length of a full step apart in the manner shewn in Fig. 104. Figs. 104 to 106 shew the various phases of this exercise, which may be called Walking sideways in groups to the right with full steps.
8. The same as Exercise 7, but the steps are made at command.
9. The same as at 7, but the distance between each patient and his neighbour is reduced to a half-step.
10. The same as at 9, but the steps are made at command.

Fig. 105.

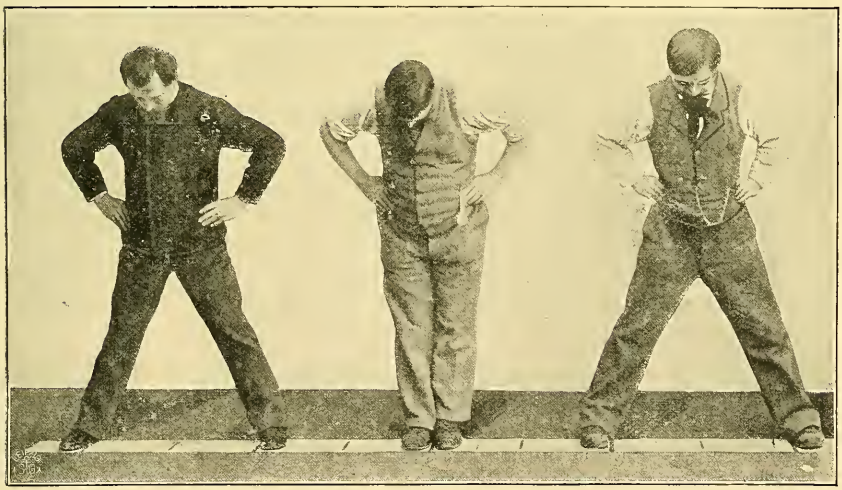

Fig. 106.

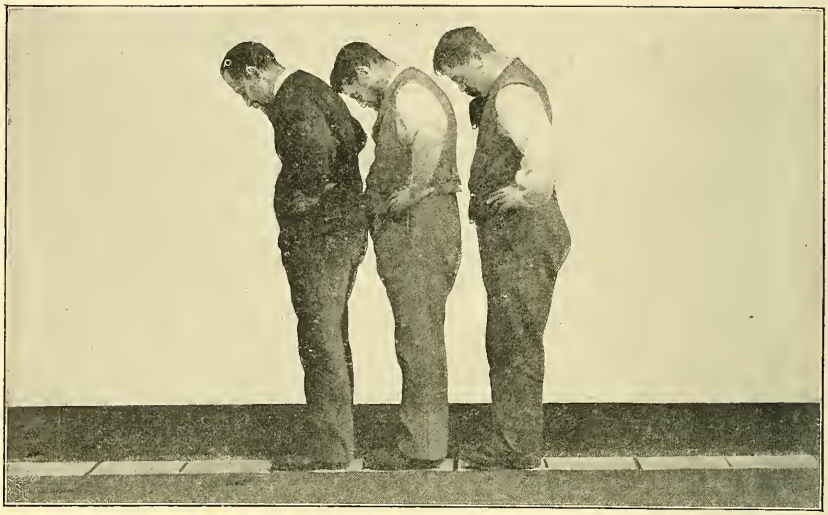

Fig. 107.

Fig. 108.

Remarks.

Practising in groups requires that the patients be able to move about freely and to keep their lower limbs under perfect control. Its value lies in the proper determination of the time required for the execution of the movement—in short, in the "tempo" of the movement. We have already mentioned, when a patient has to make a certain movement at command, that he does not carry it out at once, but that he seems to be searching for the group of muscles which are necessary for the movement, and that he endeavours to make up for this delay by accelerating the contraction of the muscles, hence the

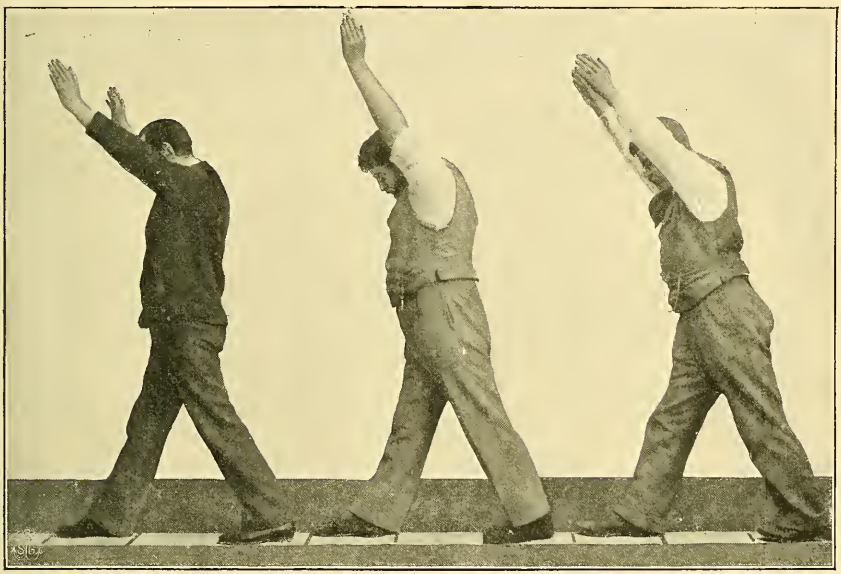

Fig. 109.

jerking or thrusting movement. The combined exercises which we have described are so devised that they obviate this irregularity on the part of the patients by compelling them to step out with the same foot and at the same time as the man in front of them, and to put their feet down in the same place which he has just left. The leader should, therefore, be a skilled attendant, or else a patient with only a very slight ataxic disturbance who is able to move at the moment the word of command is given, who does not waver or hesitate, and who has such good control over his antagonist muscles that he can carry out every movement of the exercise without mistake or irregularity. He should quicken his step and slow down alternatively, and the

patients behind him will have to copy his example. If devised with proper regard for the requirements of the patients, these group exercises possess great value, for they enable the patient sooner than any other to move about out of doors. If the arms are raised and held in various positions as shewn in Fig. 109, the difficulty of the exercise can be graduated to a nicety.

Another group of common exercises serves to imitate as much as possible the conditions in which the patients find themselves when walking in the street or meeting people in a corridor and so on :

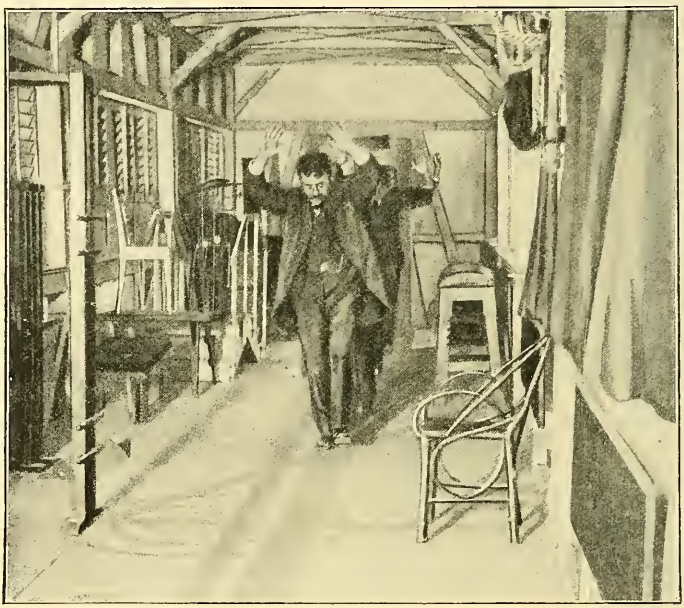

Fig. 110.

11. Two patients, walking towards each other, meet in the middle of the practice-room. The one continues his way ; the other has to make way on his right or left side and then resume his former direction.

12. The same exercise as 11, but the medical attendent names the person who has to make way for the other.

13. A number of chairs are placed in the room at distances of about 2 yards. Two patients walking in different directions have to walk between the chairs, describing figures-of-eight. They have to avoid knocking against one another or pushing the chairs out of place. This exercise can be further modified by groups of patients walking in

single file taking the place of the two single patients, or by shortening the distance between the chairs (Fig. 111).

14. Exercises 11, 12, 13 may also be further varied by the introduction of such acts as are common in ordinary life, such as raising the hat, shaking hands, looking back, and so on.

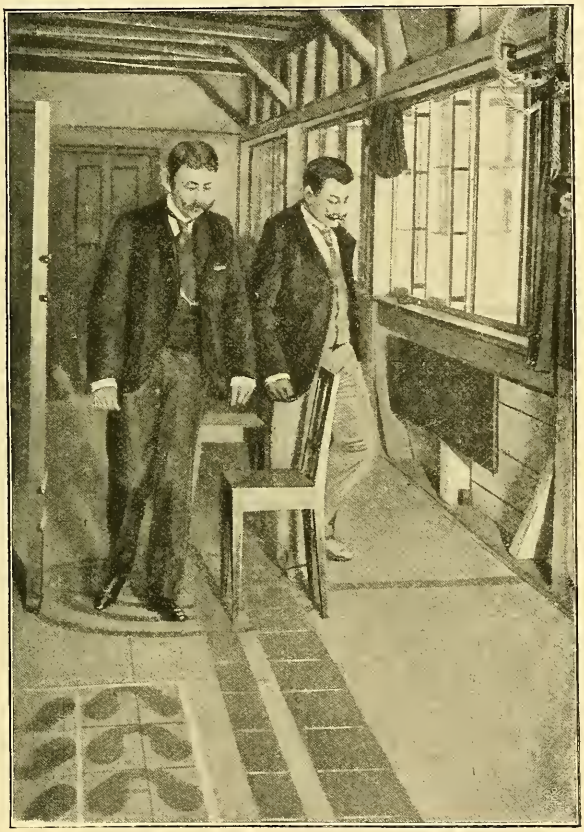

Fig. 111.

15. The walking is combined with such manipulations as putting on or taking off the coat (Fig. 112).

16. A further, though very tiring modification of these exercises, may be introduced at the end of the course of treatment; namely, the patients, meeting in the middle of the practice-room, try to push one another off the path; this may be done in various ways, but should always be done under strict control by the doctor. This exercise should not be continued for longer than one-half to one minute at a time.

ATAXIA OF THE UPPER LIMBS.

Tabes dorsalis affects the upper limbs in the same manner and almost to the same degree as the lower limbs. Muscular hypotonia, loss of coordination and of sensibility, especially in the skin of the fingers and palms, characterize the tabetic affection of the upper limbs. The loss of sensation will, of course, be less felt during the coarser manipulations, such as carrying a stick or holding on to a rail, but

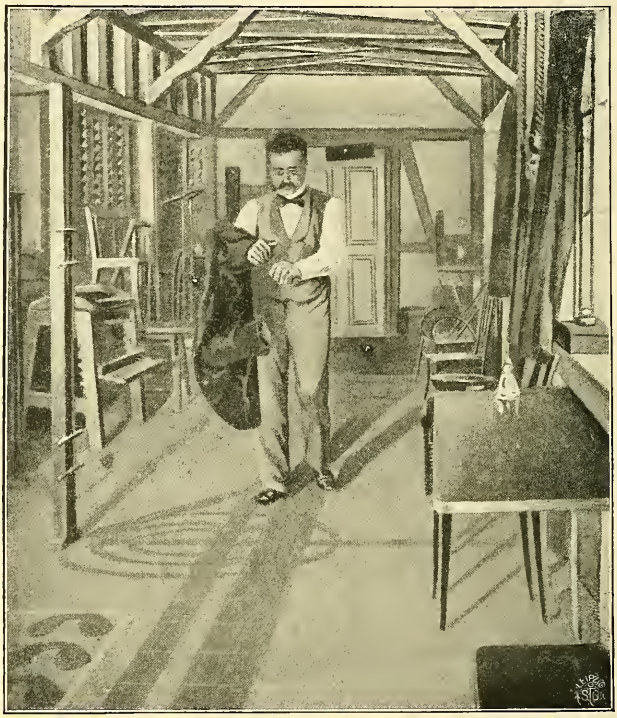

Fig. 112.

will at once become very obvious if finer tactile impressions are needed, such as are necessary for holding a pencil, a match, buttoning the coat, and so on. The loss of coordination in the upper limbs is, of course, as amenable to treatment as that of the lower limbs. The loss of sensibility, on the other hand, cannot be influenced by movement treatment. Fortunately, there is no direct parallel between the loss of coordination and that of cutaneous sensibility, so that very often severe loss of coordination is only accompanied by slight loss of cutaneous sensibility; in such cases the prognosis is very good.

When, however, the opposite is the case, and there is little loss of coordination, but pronounced loss of sensibility, the prognosis, naturally, is unfavourable; such patients remain unable to perform the most ordinary manipulations. Theoretically, ataxia of the upper limbs gives a more favourable prognosis, because there is no necessity for balancing the weight of the body or danger from accidents; but practically the results are satisfactory only when the loss of cutaneous sensibility is very slight. Further, the prognosis depends on the nature of the profession or trade of the patient. A labourer, porter, messenger, will be able to continue his employment for a long time, whereas persons whose work or occupation demands the perception of fine tactile impressions, such as watchmakers, draftsmen, musicians, writers, and so on, lose their employment quite early in the course of the disease.

THE EXAMINATION FOR ATAXIA OF THE UPPER LIMBS.

The examination for ataxia of the upper limbs is conducted on the same lines as that of the lower limbs.

The Shoulder-joint.—The arm, hand and fingers are to be kept extended while the limb, in the shoulder-joint, describes horizontal, vertical, diagonal and rotatory movements. By means of an instrument similar to a perimeter, the movements of the shoulder-joint can be graphically reproduced. The patient, sitting in front of the instrument, keeps his elbow and wrist-joint extended, and, holding a pistol-shaped wooden instrument in his hand, to the distal end of which a pencil is attached, he moves his arm up and down or horizontally, or in whatever direction is demanded of him, registering the amplitude of the movement on a strip of paper attached to the perimeter. The radius of the perimeter should approximately be as long as the upper limb of the patient.

The Elbow-joint.—The examination of the mobility of this joint is very simple, and is confined to flexion and extension, pronation and supination of the radius. When the arm is fixed, incoordination of the elbow-joint produces peculiar jerky, "staccato" movements. By holding the arms in various positions, the different factors which influence the movement in the elbow-joint may be studied.

The Wrist-joint.—Loss of coordination in this joint becomes visible through a marked alteration of the movements of the hand. Flexion, extension, abduction, adduction, and rotation become more or less awkward, jerky, and interrupted. There is often marked wrist-drop without paresis.

The Fingers.—The functional disorder of the movements of the fingers, more than that of any other part of the body, depends on the degree to which their sensibility has been affected. The position in which the fingers are being held is very characteristic. Instead of that slight and uniform flexion of all the finger-joints which makes the fingers able at once to perform the most delicate movements, there is regularly to be found marked extension of the last two phalangeal joints, and the fingers can only be flexed in the metacarpo-phalangeal joints. This condition is analogous to the tabetic stiffness of the knee and ankle joints. One result of this continued extension of the phalangeal joints is that objects are not grasped in the ordinary way, but are held by the volar surface of the extended thumb pressing them against the volar surface of the second phalanx of the extended forefinger or middle finger. The same attitude of the fingers is assumed in writing and other complicated movements. The patients have the greatest difficulty, if they at all succeed, in forming a ring with the thumb and one of the fingers; this movement can, therefore, be used with advantage for the determination of the amount of functional disorder present and for the re-education of coordination.

THE TREATMENT OF THE UPPER LIMBS.

The exercises which are intended for the treatment of ataxia in the upper limbs may be divided into three groups:

1. Simple contractions of muscles.
2. Practice on special apparatus.
3. Practice of movements normally performed by the patient, such as writing, drawing, and so on.

Before entering into a description of the various exercises, we should like to draw the attention of our readers to the peculiar position in which the tabetic persons hold their upper limbs. Healthy subjects when working keep their arms slightly abducted, their forearms somewhat flexed, and the hands extended so that forearm and hand are in a straight line; tabetic patients are frequently seen to keep their arms close to the body and the wrist-joints flexed, while the fingers are extended in the peculiar manner already described. The cause of this abnormal attitude of the upper limbs is to be found in the loss of articular and muscular sensation. The patients are unable, without continued control by the eyes and excessive muscular exertion, to maintain the balance of the limbs. The arm and hand are suffered to follow the influence of their own weight, thus producing apposition

of the arm and ankle-drop, just as in the lower extremity we see plantar flexion of the foot and outward rotation of the thigh.

APPARATUS FOR THE UPPER LIMBS.

I. The Triangular Block (Fig. 113).

A prismatic wooden block about 18 inches long, the bases of which form equilateral triangles of 2 inches lateral length, is so prepared that one edge remains sharp, the second has been bevelled off, while the third is grooved. The block is placed on a table in front of the patient in the position indicated by the drawing, with the grooved edge up. The patient is given a stout pencil, and is requested to draw the point of the pencil along the groove from the further end of the block towards him, at the same time holding his fingers and wrist-joint perfectly stiff. This exercise is by no means easy, especially when the pencil is to be held with the slightest force. At first the pencil will often leave the groove; gradually its progress along the groove becomes more steady, although by no means free from wobbling. The object of this exercise is to teach the patient to keep his arm raised in a certain position, and to make small excursions in the horizontal plane, which bear a certain proportion to the larger excursions in the elbow-joint. The absolute magnitude of the movements in the two joints of course vary at every moment, but their excursions must continue to have the same relations to one another if the movement is to be coordinate and suitable for the purpose for which it was intended. Each error of innervation, each incoordinate movement, is registered by the pencil on the block, thus giving the patient and the doctor an opportunity at once to correct the faulty movement. By altering the position of the block on the table a series of variations may be introduced. The movement of the pencil along the groove must be slow

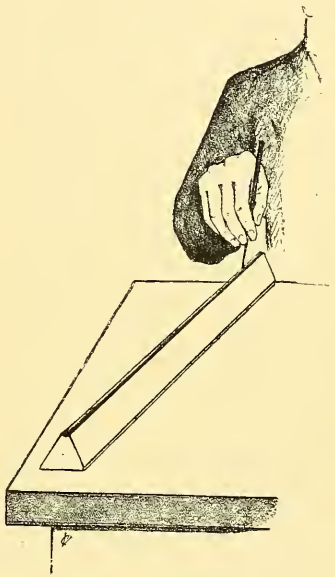

Fig. 113.

and uninterrupted, and equal force must be used. The tabetic patient will experience the greatest difficulty at first to conform with these requirements, because slow and continued movements require more prompt and correct innervation than jerky, thrusting movements.

A more recent model is the one represented in the following illustration (Fig. 114). It can be moved round a vertical axis as well as horizontally, and can be fixed in any position, so that it does not

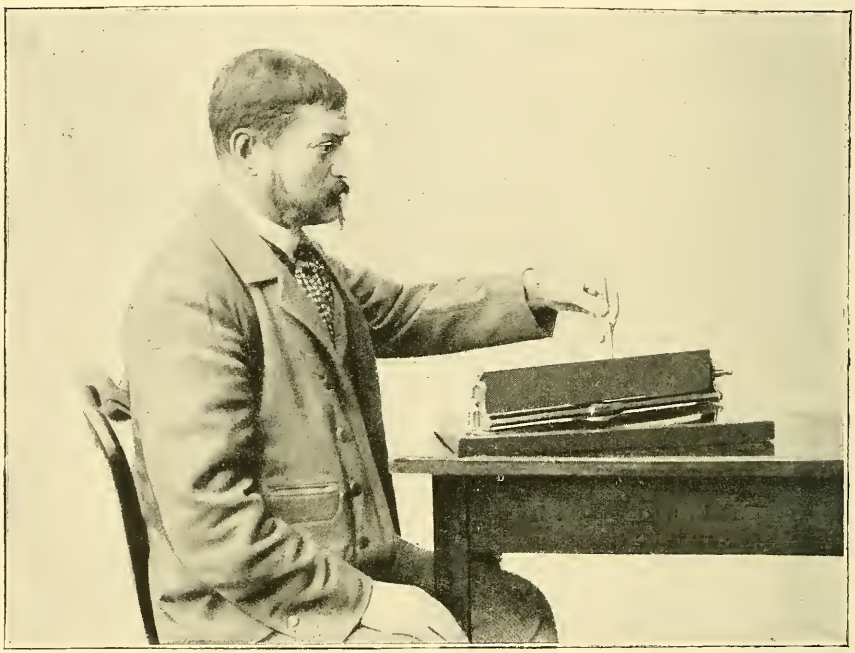

Fig. 114.

require to be held in its place. While one hand is practising the other may rest.

II. The Perforated Board.

The practice on the triangular block requires a continuous movement, during which very little progress is made at any given movement. In this series of exercises, however, quite a different mode of progress is introduced. The board, about 12 inches square (Fig. 115), bears a number of holes made just large enough to receive the tip of one's finger, which are arranged at regular intervals along the sides of the square, with one hole in the centre; they are also numbered. The board is placed on a table in front of the patient, who, with raised

arm and extended forefinger, waits for the word of command from the doctor. A number is called, and the patient, as quickly as possible, puts the tip of his forefinger into the hole next to the number called out. At first the same number is called several times in succession, until the patient is able to coordinate his movements with sufficient celerity, after which a different number should be called each time. The patient proceeds from numbers called out seriatim to numbers called out at random; the pace quickens until the tempo is about the same as would be required if the practising person were a healthy subject. *As in the former group of exercises, so has here the patient an opportunity of correcting at once any mistake or irregularity he may have made.* A more recent model (Figs. 116 and 117) enables the patient to practise with both hands at the same time or alternately, and on a horizontal, oblique, or vertical plane.

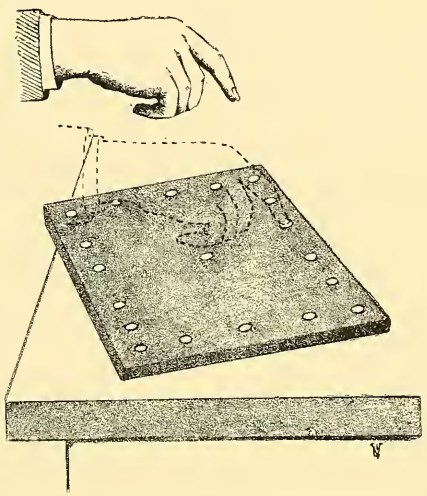

Fig. 115.

III. The Peg Board.

Instead of holes, a series of pegs are fixed in a board. This board can either be used in the same way as the perforated board, or the patient may use it in the manner indicated in the drawing.

IV. Board with Loose Pegs.

Instead of having pegs fixed in the board, they may be provided loose, and the patient asked to fix them in the holes. Brass pins with wooden tops, as used for electric switch boards, will be found very suitable. Fig. 119 gives a good idea of the use of these pins. The patient has first to pick up the pins, which is by no means easy for him, then fix them in the holes indicated to him, take them out again and put them into other holes, and so on. All this requires a very great amount of coordination. The patients at the beginning of the practice with the pins find it very difficult to pick them up; they usually hold them

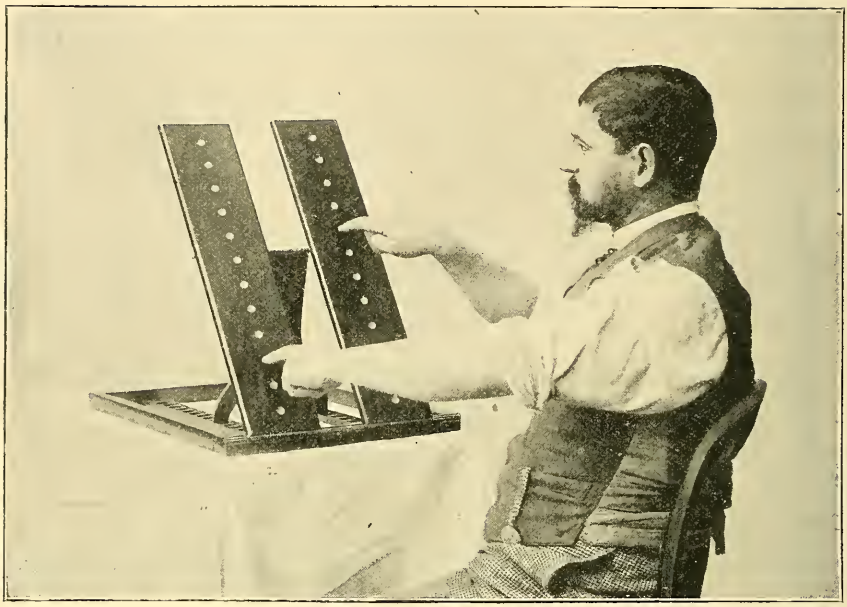

Fig. 116.

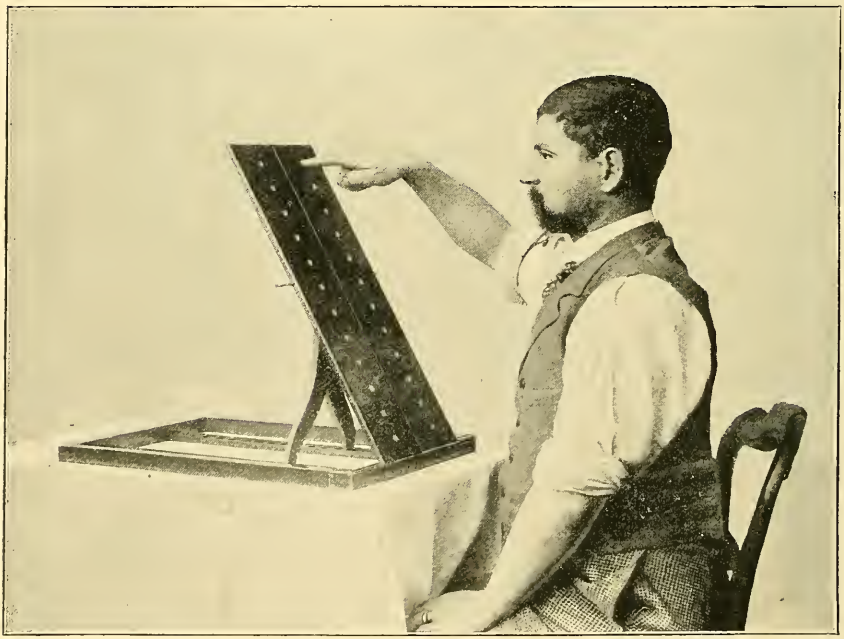

Fig. 117.

between the end phalanx of the thumb and the second phalanx of the forefinger. While in former exercises the patient had to concern himself with one object only, he has now to divide his attention between the board and the loose pins, which makes this exercise much more difficult than any of the preceding ones.

V. Coloured Balls suspended from a Bar.

Another very useful apparatus consists of a series of coloured balls suspended from a horizontal bar. The balls are of lead, and of various sizes and colours (Figs. 120, 121, 122). The largest ball is made to swing, and the patient is requested to catch it. At first the patient is allowed to choose for himself the moment when he will catch the ball, which, of course, will be the moment when the ball has reached the greatest amplitude, and is apparently at a standstill for the moment. The patient will be seen to watch for this moment with the muscles of his arm in a state of tension, and when the ball is swinging towards him he will make a grab at it. Later the patient may be induced to try to catch the ball at a less favourable moment. Still later the ball has to be caught at command (Fig. 121). The larger the ball the easier is the exercise. When the patient has become proficient enough with one ball, he may practise with two or three balls which are swinging at the same time; or he may be told to let go one ball and catch another, and so on. The balls should be caught with the finger-tips, not the whole hand, as is the tendency among tabetic patients. The bar from which the balls are suspended can be lowered or raised as may be required.

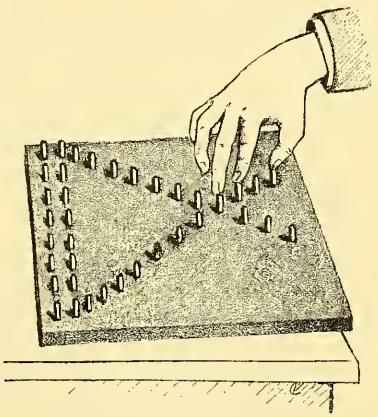

Fig. 118.

VI. Round Discs (Fig. 123).

Round wooden discs of different size, thickness and colour (from the size of a sixpenny piece to that of a five-shilling piece), are to be piled up by the patient, using either discs of the same size or of different sizes, beginning with the largest and ending with the smallest, choosing all of the same colour or of various colours; here, again, the

patient begins by choosing the discs himself, and ends by picking up the discs at command.

VII. Diagrams for Copying.

As an exercise preliminary to the instruction in handwriting, we use various simple diagrams (Fig. 124), consisting of straight lines, angles, spirals, zigzag lines, and circles of various diameters. These patterns are drawn on stout cardboard, and should be used for following the outline with a pencil. They give a possibility for comparing from

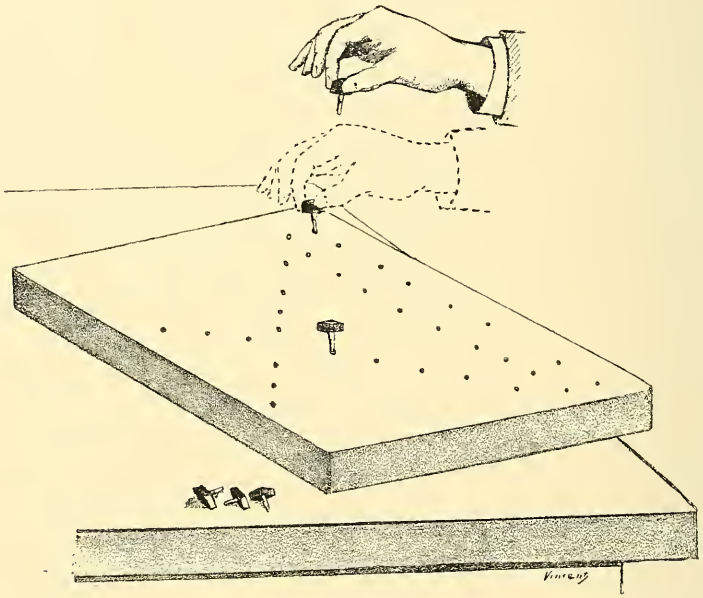

Fig. 119.

day to day the progress made by the patient. A comparison of the patient's work on successive days gives the doctor and the patient an opportunity to judge of the progress made from day to day. Following a straight line with the pencil is easier than the practice on the triangular block; but to correctly copy angles or zigzag lines, and above all circles, requires a constant change of innervation, and this makes that exercise rather difficult. Figs. 125 to 128 give samples of a patient's drawing at the beginning and at the conclusion of a course of treatment of the upper limbs. Fig. 129 gives a facsimile of the writing of the same patient. The line at the top

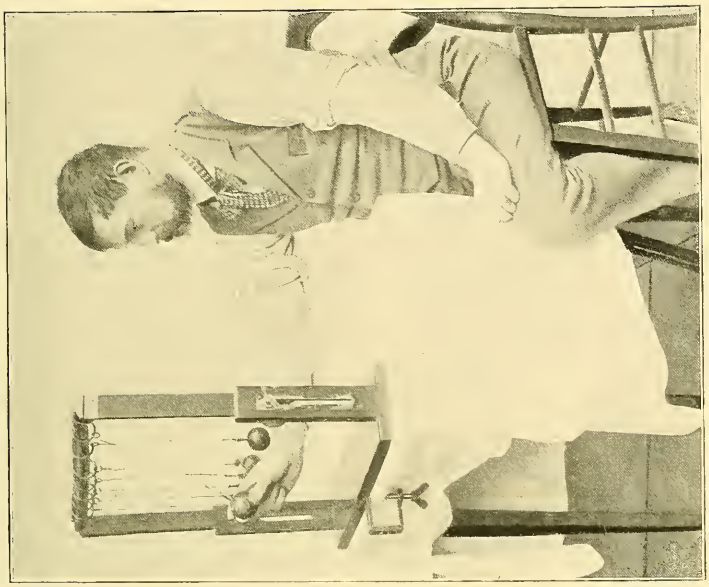

Fig. 121.

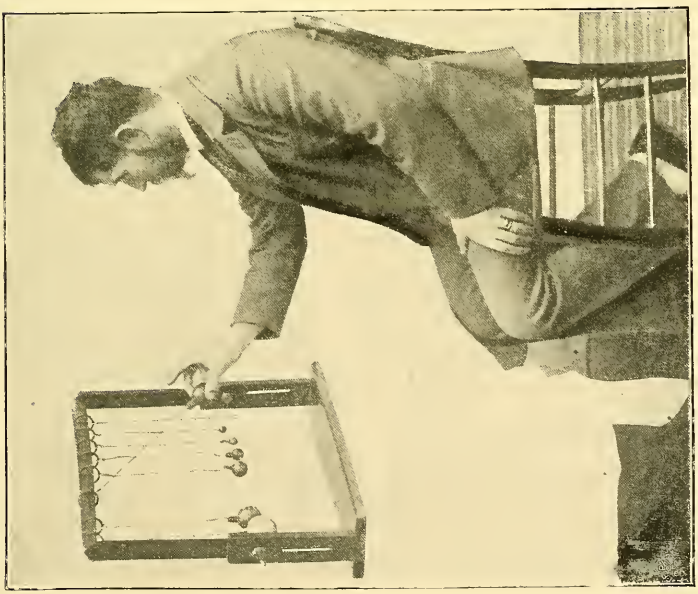

Fig. 120.

shews the patient's handwriting at the beginning of the treatment; the second line, six weeks after the commencement of the treatment. In this, as in every other series of graduated exercises, the patients begin with the easiest and gradually proceed to more difficult tasks, but it would not be wise to confine a patient to one exercise until he has thoroughly mastered it before proceeding to the next difficult, lest the monotony of the practice kill in the patient the interest in his work. As soon as the patient shews signs of flagging interest, another set of exercises should be commenced, and it will often appear, in consequence of the fresh interest which the patient takes in his work, that he performs his new but more difficult task more correctly than former but easier exercises. During each lesson a series of apparatus should be used. How many and what apparatus should be used depends entirely on the degree of ataxia, the general health and intelligence of the patient. Each patient should practise one to three times a day, for not more than three-quarters of an hour each time. After every new exercise an interval of a few minutes should be made. The patient should always practise in the presence of the doctor, who alone, in the absence of any feeling of fatigue on the part of the patient, has to determine when the practice should be interrupted, and so on.

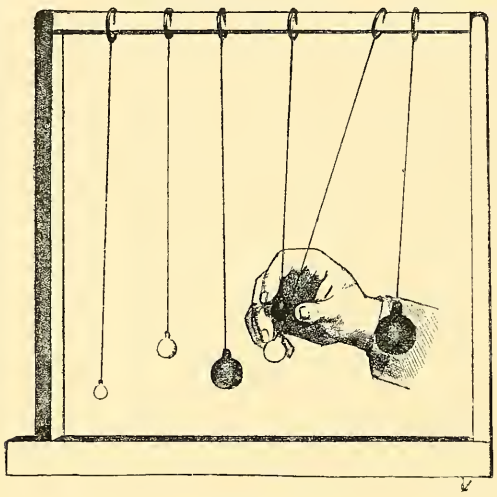

Fig. 122.

The number of apparatus can, if required, be increased or varied without difficulty. The patient should be requested to dress himself without aid, to tie his necktie, to help himself at table, play the piano or any other musical instrument, and practise writing with pen and ink rather than with a pencil. Playing cards requires many and very complicated movements, and should on that account be encouraged.

Fig. 123.

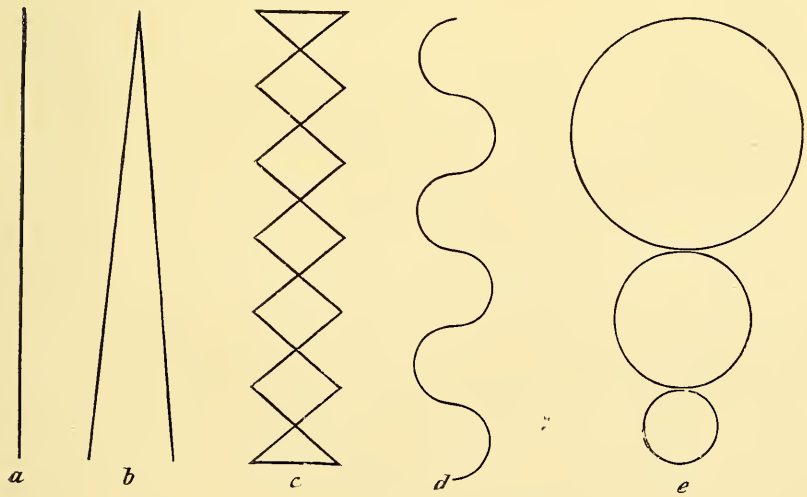

Fig. 124.

ATAXIA OF THE BODY.

We have already shewn how slight alterations of the position of the legs are attended by a corresponding change in the position of the body. The joint which is mainly instrumental in bringing about these changes is the hip-joint; but the precise and safe equilibration and the prompt reaction to the wants of the moment are made possible only by the hip-joint cooperating with the movements of the vertebral column. The simplest form of ataxia of the body is represented by the swaying to and fro which is noticeable when tabetic persons sit on a form without any support to their back. This symptom is very rarely seen when the patients have their eyes open, but appears at once when the eyes are shut. This symptom is present when the majority of the vertebral muscles have partially or entirely lost their sensibility As so high a seat of the tabetic lesion is relatively rare, one does not, as a rule, observe that swaying movement when the patient is sitting. One symptom, however, is always present, namely, an alteration of the movements in the hip-joint. This symptom is so constant that it may be said that the degree of loss of sensibility of the trunk muscles is directly proportioned to the loss of sensation in the hip-joint. That such is the case may be easily demonstrated in almost every patient, and the symptom will be found to be accompanied by a certain stiffness of the vertebral column in consequence of the tension of the muscles that run from the spinal column to the pelvis. This stiffness of the vertebral column is characteristic of a certain stage of the disease. On the amount of loss of sensation in the hip-joint, and on the integrity of the muscles surrounding it, depends whether the movements of the trunk which are absolutely necessary for the purpose of locomotion take place in the hip-joint with sufficient freedom and precision or not. Sometimes the resulting instability is so great that in the erect posture the patient does not dare move his body for fear of losing his balance. In such cases all independent locomotion has ceased a long time ago.

Fig. 125.

Fig. 126.

When the tabetic process has reached higher sections of the cord—say, beyond the first lumbar vertebra—the condition of the patient

as regards the stability of the trunk becomes still worse. Although such cases are decidedly the exception, they are by no means so rare as was believed at one time. The muscles which are chiefly affected, as far as can be clinically ascertained, are the ileo-psoas, the quadratus lumborum, the abdominal muscles, and the short extensor muscles of the vertebral column. The result is ataxia, or more or less temporary paresis, or a peculiar loss of tone resulting in abnormal mobility of

Fig. 127

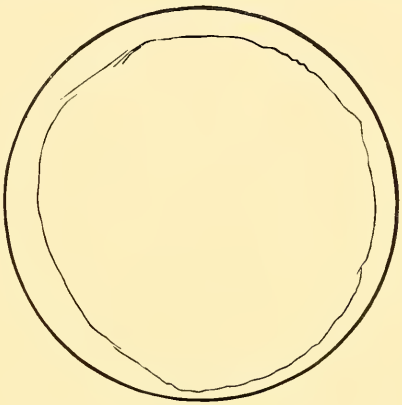

Fig. 128.

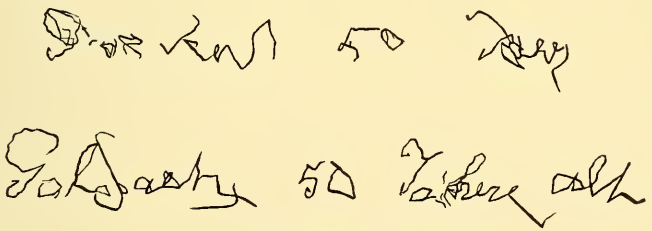

Fig. 129.

the spinal column, or, and this is most frequently the case, a combination of several or all of the symptoms in some or all of the aforementioned groups of muscles. Such patients are not only unable to move about by themselves; they also move with great difficulty when in bed, and when sitting up the pliability of their bodies makes that posture very tiresome. They are therefore permanently bedridden, with the diagnosis "tabetic ataxia of the legs," when in reality the ataxia of their lower limbs may be very trifling when compared with the ataxia of the body, which forces them to keep to the bed.

The treatment of the ataxia of the body is governed by the same principle as that of the extremities; the exercises, of course, are chiefly walking exercises, but in special cases movements may be added which are intended to re-educate the muscles of the trunk.

DURATION OF THE PRACTICE OF MOVEMENTS.

The practice of any movement causes tabetic patients much fatigue and mental strain. If the practice be continued beyond the point when the patient begins to shew signs of inattention or fatigue, the good effect otherwise produced by the practice will be lost again, for the exercises are useful only when the attention of the patient is fully concentrated on them. The necessity of concentrating his attention, the muscular exertion, the fear of accidents, the annoyance which the patient feels, especially in the beginning of the treatment, because his limbs will not "obey orders"—all this combines to produce rapidly a most marked feeling of fatigue. It becomes then the duty of the medical man who superintends the practice not to continue the practice of each movement for longer than three or four minutes; in severe cases, or when the patient is in a bad state of nutrition, one-half to one minute will be quite sufficient, at any rate, until the patient has become strong enough to bear the strain of longer-continued practice. Exercises in the recumbent position, even if they be rather difficult, are generally easier for the patient than those to be practised in the erect position, like walking. Each "course" comprises a series of individual exercises which are graduated according to a fixed plan, and which altogether should not last longer than half an hour, inclusive of the rests between the various exercises. No new exercise should be begun before the patient has completely recovered from the excitement and fatigue caused by the previous exercise. It must be remembered that tabetic patients have more or less completely lost the sense of fatigue; consequently, in determining whether a tabetic patient is tired or not, we have to have recourse to another symptom—namely, the action of the patient's heart. The pulse usually rises to 120, or even to 160, beats per minute; the number of beats is in direct proportion to the difficult nature of the movement which is just being practised. It should therefore be the rule—at the beginning of the treatment, at any rate—frequently to examine the pulse of all patients, and to interrupt the practice as soon as the pulse has reached a certain number of beats. The interval of rest should last until the number of heart-beats of the patient has become normal

again. As the treatment continues, the excitability of the heart gradually diminishes, but in most cases the pulse will remain a trifle more frequent than one would expect, considering the age of the patients. If the pulse remains or becomes frequent at the slightest exertion, it is a sure sign that the patient is in a state of tabetic cachexia, characterized by anæmia, muscular weakness, rapid pulse, and so on; such patients must be very carefully treated. Two courses of exercises a day is the average rate of practice. To go beyond that number is hardly safe, unless each course be made very short, and the patients are robust and determined, and are making good progress, in which case they may have three courses a day. In the morning the patient practises the movements which are designed for the recumbent position; in the afternoon he should take part in the class exercises, when the patients practise standing or walking. As a third exercise the patient may be allowed to go out for a walk; he should not walk for more than ten or fifteen minutes at a time, and frequently sit down to rest. If one is successful in determining for each patient the daily amount of exercise that just suits him, the patient will be found to recover quickly from the fatigue caused by the various exercises; that each successive exercise is followed by an increase of strength on the part of the patient, who will gladly inform one that at the end of a course of movements he feels more fresh and vigorous than before.

THE TREATMENT OF HYPOTONIA.

The loss of the normal muscle tone, with its deleterious effect on the joints, may influence the course and result of the movement treatment in various ways. The danger of dislocation of the foot which results from the relaxation of the ankle-joint, and the steps to be taken for its prevention, have already been discussed. It is, however, obvious that we have at present no means of treating the hypotonic condition itself, but only its consequences; in fact, it is the treatment of the consequences of the hypotonia, of the muscles and joints alone, which forms the subject of our study. The treatment of the cause of hypotonia is, indeed, identical with the treatment of the cause of tabes dorsalis, and therefore outside the scope of this work.

Normally, the calf muscles and the flexor muscles of the thigh hold the knee-joint in a state of slight flexion, which is seldom changed into a state of extension. The coordination of the flexor muscles of the back, and the extensor muscles in front, is lost when-

ever sensibility in the knee-joint and the surrounding muscles becomes impaired. If, as is usually the case, the flexor muscles become hypotonic, but the patient is at the same time able, by means of forced contraction of the extensor muscles, to fix at each step the thigh-bone against the tibia, so that the two bones apparently form a straight line or a slightly obtuse angle open in front, then a new and relatively steady movement of the limb may be produced which lends a characteristic stiffness to the gait of the patient. On the other hand, if hyperextension of the knee-joint cannot be produced by the patient, be it that the weight of his body is too great, or he himself too timid, or that his knee-joint has become perfectly anæsthetic, then no good result can be produced by the movement treatment. An interesting case in point is the following: The patient in question was a very tall and stout man, with pronounced loss of sensibility as regards active and passive movements in the hip and knee joints, but with very little hypotonia of the knee-joint. The anæsthesia of the hip-joints induced him to hold his body erect and stiff, and to transfer his centre of gravity further back than is usual; this, of course, produced a tendency of bending the knees, which made walking almost impossible. Had this patient, however, had a marked degree of hypotonia of the knees, he would have kept his body bent forward, and with the help of a stick he could have walked tolerably well. As it was, the patient derived hardly any

Fig. 130.

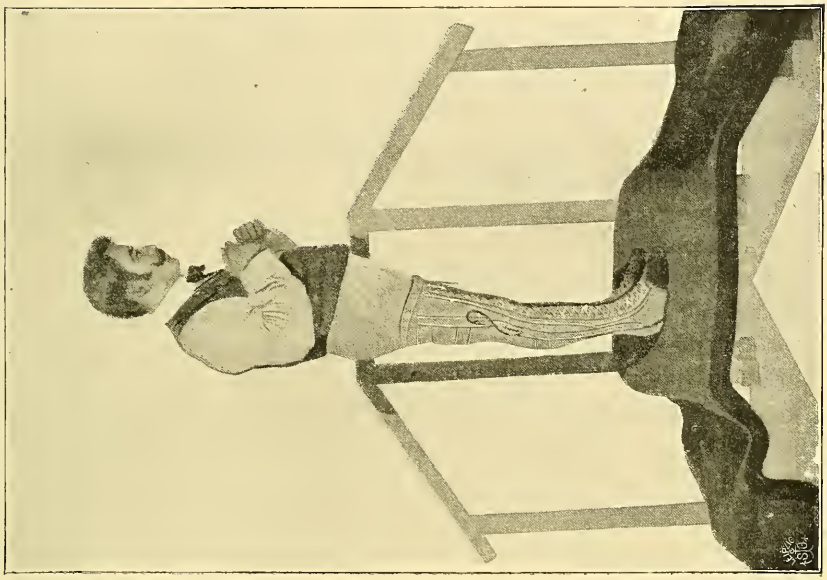

Fig. 132.

Fig. 131.

benefit from his treatment, thus shewing that under certain conditions the absence of hypotonia may be as detrimental to the result of the movement treatment as an advanced state of hypotonia.

The hypotonia of the knee-joint may produce a genu recurvatum of such a degree that the thigh and leg form almost a right angle. In this respect the two limbs are not always equally affected. One is generally more hypotonic than the other; this upsets the balance of the body almost completely, and is very tiring to the patient. Such cases need the application of an orthopædic apparatus, which prevents the knee from becoming too much hyperextended. Theoretically very simple, such an apparatus presents many practical difficulties; for instance, it is very difficult to fit on the limb, unless it reaches down to the ankles and up to the hip-joint. Such an apparatus consists of two separate cases for the thigh and the leg, which at the level of the axis of the knee-joint are connected by a joint possessing a contrivance by means of which the backward movement of the knee-joint may be graduated. The whole apparatus rests upon a foot-piece, which prevents the ankles from turning over. Figs. 130 and 131, which have been taken from a case of general congenital hypotonia in a boy, illustrate the attitude of the patient before and after the application of the apparatus. A further difficulty arises in consequence of the tendency of the "corrected" knee-joint of "doubling" under the weight of the body. This can be prevented only by means of a movable "catch," which the patient may apply or remove, thus enabling him to release the joint when sitting down. The weight of such an apparatus is considerable. We have therefore replaced the stiff cases by stockings made of soft dog leather, to which the metal fittings are fastened. On either side of the knee are fixed strong steel spiral springs, which prevent both hyperextension and sudden flexion (Fig. 132). Much yet remains to be done in order to solve the vexed problem of the orthopædic treatment of tabetic hypotonia.

THE RESULTS OF THE MOVEMENT TREATMENT.

Medicine possesses few therapeutic agents of which it can be said that their action is absolutely certain. If, however, one is permitted to look upon a manifest *improvement* as a favourable result of any treatment, then it cannot be denied that our method of treating tabetic ataxia, based as it is on the *practice* of ordinary movements rather than on vaguely-defined athletic or musculo-therapeutic principles,

is in every case attended by a decided improvement of the incoordination.

The unfailing certainty of the improvement, and the fact that it is an improvement of a symptom which has been caused by an organic lesion, attach special interest to the movement treatment. The symptom against which our system of treatment is mainly directed is a motor disturbance which has its origin, however, not in a diminution of the motor function of the muscles, but in a loss of sensibility. The means by which the improvement is brought about with such unfailing certainty is one that from daily observation of the healthy organism is well known to be effective. It is based on the cardinal quality of the nervous matter of being "exercised," provided that the motor apparatus itself is intact. If one considers the reacquisition of ordinary movements which had been lost in consequence of partial or total loss of sensibility, a task which in principle is identical with the acquisition, by a healthy person, of a complicated combination of difficult movements, such as rope-dancing, for instance, then it will have to be admitted that in both cases the same factors must influence the result in precisely the same manner.

There is first of all to be considered the natural disposition, alertness and ability for muscular exercise. As far as can be ascertained in individual cases, these qualities have not been greater before the onset of the ataxia than they are found to be during the movement treatment. *Ceteris paribus*, the more skilful among the patients will make more rapid progress; the best results have been achieved by the author with officers and others who had been following athletic sports. Another important factor is the personal courage of the patient. Over-apprehensive or cowardly patients who will not risk to make the slightest movement without someone being near to support them will have to practise for a long time before any definite improvement may be noticed. One of the best results was achieved in a patient of forty-two years of age, who combined a rare amount of persistence and attentiveness with great courage and will-power. He used to cross the streets with a slow and deliberately measured step, and was not at all to be disturbed by the wheeled traffic, because, as he put it to himself, it was the duty of the driver, not his, to see that he was not run over. In another not less favourably treated case, a patient, who was a great traveller, had the courage to traverse Central Asia, although he had to be tied to the saddle. It is a well-known fact that courageous people remain masters of their movements much longer

than anxious or weakly people, because they fight against the manifestations of the disease with all their might.

Of the greatest importance, however, is the time which the patients can devote to their treatment. The longer the movement treatment is continued, the more certain and lasting is the improvement. The longer the treatment is continued, the closer does the patient approach, not only to the normal standard of motor capacity, but also to the normal standard of accuracy of movements. In severe cases of ataxia, at any rate, the aim should be to restore the patient to normal motor capacity—that is, to enable him to use his limbs again as freely as a healthy person would do ; to promise him more would be unwise, if we remember that the re-education of his coordination depends entirely on how much or how little of his muscular and cutaneous sensibility has been left undestroyed by the disease, and that the hypotonic condition of the joints has so altered the structures forming and surrounding the joints that not much actual improvement can be expected in this direction from the movement treatment. The necessity of controlling with the eyes the movements of the legs is also sufficient to produce a permanent alteration in the patient's manner of walking, to which must be added the stiffness of the legs, which is the result of the efforts made by the patient to overcome the hypotonia of his knee-joints. The ideal result of the movement treatment must always remain the restoration of the normal accuracy, character and velocity of the movements, a result which in many cases was actually achieved ; the practical aim, however, which should be reached in all cases is the restoration of the normal power of locomotion and of those movements which are necessary in the pursuit of the profession of the patient. When this latter result has been obtained, the therapeutic task may be considered to be over. Whether, beyond the restoration of the patient to the pursuit of his trade or profession, the movement treatment should be continued until an almost absolutely normal state is reached, depends on many external circumstances, not the least of which is the question of expense and expediency. It is necessary in order to achieve such a result that the patient should continue the treatment for many months, if not for some years, and, secondly, that the treatment should be continued in sanatoria or other institution, for such lengthy and not at all inexpensive treatment is clearly outside the possibilities of treatment at the house of the patient.

THE MOVEMENT TREATMENT IN THE PREATAXIC STAGE.

We have already shewn that even in the so-called preataxic stage of the disease there is more or less disturbance of coordination, although the patient may not suffer from actual loss of movements; besides, even if in the early preataxic stage of the disease the patient does not already shew any actual loss, he is threatened with more or less complete loss of coordination. We have seen that patients who before the development of their incoordination had been in the habit of training their muscles, such as soldiers, athletes, acrobats, have a very good chance of regaining the coordination of their movements. Is it, then, not rational to recommend that already in the preataxic stage the patient should be taught how to keep his movements under control, instead of waiting until ataxia is firmly established? Ataxia sometimes develops suddenly, as in a case which came under our observation, where the first symptom of ataxia which the patient noticed was that one day he found himself suddenly unable to mount a tramcar in motion. Another patient first noticed that he was unable to look up to the painted ceiling of the Sixtinian Chapel without staggering.

THE TREATMENT OF THE MUSCLES OF THE EYEBALL.

The paresis or paralysis of the muscles of the eyeball must be considered to be analogous to the tabetic paralysis of the other muscles of the body. The cause of this paralysis, like that of the muscles of the limbs and trunk, must be sought in the loss of sensibility, a view which seems to be justified by the variable intensity and the oftentimes sudden disappearance of the disturbance. The paresis of the muscles of the eyeball, the varying intensity and reaction to acts of volition of which are almost pathognomonic, is amenable to treatment. The treatment consists in systematic concentration of the will on the insufficient muscle, and in attempts at fixing objects with the eyes. A perimeter will be found very useful. An active interference is necessary in order to obviate the development of retraction of the antagonist, an event which is not at all uncommon in tabetic muscles which have remained stretched a long time. How far this retraction of the antagonist is the cause of the permanent paralysis of the eye muscles which is sometimes met with in tabetic patients has not yet been satisfactorily established.

THE PARESIS OF THE MUSCLES OF THE LARYNX.

In the chapter on hypotonia we have mentioned the peculiar tabetic affection of the muscles of the larynx, and although in some cases peripheral neuritis may be the cause of paralysis, we would nevertheless advise the practice of breathing, speaking and singing exercises, based upon the same principle as the exercises for the other muscles.

THE PARALYSIS OF THE BLADDER.

The constant appearance of paralysis of the bladder which is present even in uncomplicated cases of tabes, even in the initial stage, when it often is the only motor anomaly that may be noticed, justifies us in separating this "paralysis" from those paralyses which are caused by a *definite and visible* motor lesion. The symptoms of tabetic paralysis of the bladder consist, first, of anæsthesia, which leaves the patient ignorant as to the state of distension of his bladder, and, on the other hand, of a motor paresis the presence of which is assumed from the more or less imperfect power of the will over the sphincter muscle. The motor disturbance is obviously dependent on the anæsthesia of the organ, which is the more troublesome as the bladder cannot be controlled by tactile impressions or by the eye. The bladder trouble varies in intensity, and not infrequently disappears altogether. The treatment consists in instructing the patient to empty his bladder at regular intervals, a plan which invariably succeeds during the early stage of the disease. In the more advanced stages, when the paresis is coupled with incontinence, it should be attempted to stimulate the sensibility of the mucous membrane and the detrusor muscle. Injections of 6 to 15 ounces of 2 per cent. boric acid solution at blood heat is sometimes very effective. When this stimulation is not sufficiently strong to produce contraction of the badder, the electric current may be sent through the distended bladder, a manœuvre which oftentimes is very effective.

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OCT 17 1905
CT 25 1905
OV 4 - 1905
EP 25 1906